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SLEEP.—This term is employed to designate that state of suspension of the sensory and motor functions, which appears to alternate, in all animals, with the active condition of those functions, and which may be made to give place to it by the agency of appropriate impressions upon the sensory nerves.

Although this may seem a complex definition of a state which seems to be in itself so simple, yet it will not be found easy to alter its character without rendering it less stringent. We more especially desire to exclude from it the abnormal condition of *coma*, in all its forms; whether resulting from the influence of pressure or effusion within the cranium, or consequent upon the poisoning of the blood by narcotic substances, or occurring as part of that inexplicable series of phenomena which are termed hysterical. The state of coma, where not so intense as to affect the movements of respiration and deglutition, is identical with profound sleep as regards its obvious manifestations; but there is this important difference, that simple sleep may be made to give place to activity by the application of appropriate stimuli to the sensorial system; whilst in complete coma, no impressions on the sensory nerves have any power of bringing back the consciousness. Between these two conditions, however, every gradation may be seen; as in the heavy sleep produced by an over-dose of a narcotic, in incomplete hysteric coma, or in the torpor resulting from slow effusion within the cranium.

The necessity for sleep seems to arise from the fact, that the exercise of the animal functions is in itself destructive of the substance of the organs which minister to them; so that, if the waste or disintegration produced by their activity be not duly repaired, they speedily become incapacitated for further use. This doctrine is now so generally admitted, that it does not seem requisite to adduce proofs in its support. The substance of muscles is regenerated during the suspension of their action in simple repose; and it is not essential that, for this purpose, a state of unconsciousness should intervene. As the substance of the nervous centres and trunks, more especially the former, undergoes a similar disintegration as a necessary consequence of its activity, this too requires a period of repose for its regeneration; but the repose, or suspension of functional activity, of the sensorial portion of the nervous system, necessarily involves unconsciousness; and it appears to be on the *nutritive regeneration* which takes place during true sleep, that its *refreshing* power depends. No such refreshment is experienced from the unconsciousness of coma, however prolonged; and there are some forms of ordinary slumber in which it is more or less deficient. The organic functions are not affected in any considerable degree by the suspension of the sensorial; for we find that not only are the operations in which these functions *essentially* consist uninterruptedly carried on, but that the muscles, nerves, and nervous centres also which are concerned in maintaining them, are enabled to sustain an unintermitted action. Thus the movements of the heart are not, in warm-blooded animals at least, normally suspended, from the first development of that organ until the close of life; the respiratory motions, in like manner, are kept up uninterruptedly from birth to death; and the propulsion of food along the alimentary canal during sleep by the peristaltic contraction of its muscular coat, the sustained action of the sphincters, the peculiar position of the eyes, and the active state of the extensor muscles of the legs in animals which sleep standing, are additional evidences that the state of continuous repose is not required for the renovation of the powers of certain parts of the nervous and muscular apparatus. To use Dr. Marshall Hall's phraseology, "the true spinal system never sleeps;" and, whatever we may think of the existence of his "true spinal" system of nerve-fibres, as distinct from those which minister to the functions of the encephalon, there can be no longer any doubt that the ganglionic portion of the spinal cord is a distinct centre of nervous action, which retains its power of actively responding to impressions made upon it, during the profoundest repose of the other centres; whilst, from the complete suspension of its functions, even for a very brief period, death inevitably results.

In following out our inquiry into the nature of sleep, and of certain conditions allied to it, we shall find it convenient to regard the encephalon as composed of four leading or primary divisions: 1. The *medulla oblongata*, which essentially consists of a prolongation of the spinal cord, including the centres of respiration and deglutition; and also having incorporated with it, without properly forming part of it, the ganglia of hearing and of taste; 2. The *ganglia of sensation*, including, with the olfactive, optic, auditory, and gustative centres, the corpora striata and thalami optici, which are probably, when taken together, to be regarded as the ganglia of tactile sensation*: 3. The *hemispheric ganglia* (Solly), or peripheral portion of the *cerebral hemispheres:* and 4. The *cerebellum.*

The *first* of these divisions really belongs to the spinal cord, and, like it, is constantly active.—The *second* appears collectively to form the true *sensorium*, to which external impressions must be conveyed, in order that they may be *felt* (each class of sensations being received through the medium of its own ganglion), and from which proceeds the stimulus to those automatic movements which can only be excited by a sensation. Such are the truly *instinctive* actions.—The *third* division, of which scarcely a rudiment exists in the lowest fishes, although it constitutes by far the largest proportion of the encephalon in man, seems to be the instrument through which *ideas* are generated, by which they are retained and made the subjects of intellectual

* See British and Foreign Medical Review, vol. xxii. p. 510.

processes, and by which voluntary determinations are formed. Impressions made upon the organs of sense would seem only able to act on the hemispheric ganglia through the medium of the sensorium; whilst the voluntary determinations, resulting from the exercise of the reasoning powers, can only act on the muscular system by the transmission of a downward impulse from the hemispheric ganglia to the automatic centres, in which the motor nerves originate.

If this be a true representation, the ordinary phenomena of sleep are not difficult of comprehension. The state consists essentially in suspended activity of the *sensorium*, so that impressions made on the organs of sense are neither *felt* nor *perceived*,—that is, neither excite sensations, nor give rise to ideas. In like manner, those automatic movements which are dependent upon sensations for their excitement are suspended; and as the torpor of the sensorium cuts off the functional connection between the hemispheric ganglia and the muscles, the latter cannot be called into activity by any mental operations in which the former may be concerned. In ordinary profound sleep, the hemispheric ganglia would seem to be in the same passive condition as the sensorium itself; so that *all* mental activity is suspended. In dreaming, however, there is a train of ideas, called up by the laws of association, and not regulated by any voluntary control, bespeaking a partial activity of the hemispheric ganglia. Into the conditions of this phenomenon we shall inquire hereafter; at present only observing, that if the sleep be deep, external impressions are as completely unperceived by the dreamer, as they are in a state of entire unconsciousness; and that, in like manner, the strongest desire felt by the dreamer to perform certain bodily movements, even when he fancies that his life depends upon them, is as ineffectual as if he were suffering from a total paralysis. If external impressions are in any degree felt by the dreamer, or his volition can exert its power over the movements of his body, the sleep is not profound, but rather approximates towards the state of somnambulism or sleep-waking, in which the sensorial as well as the hemispheric ganglia are in a condition of partial activity.

The state of simple sleep, again, is allied to that of hibernation (*see* HIBERNATION); the difference between them being essentially this, that in the latter condition, besides the profound torpor of the sensorial centres, there is a great diminution or complete suspension of the activity of the organic functions. We may trace, in fact, every gradation between the simple repose of the sensorial centres, in which the state of sleep essentially consists, to that complete suspension of all the functions of life, which is of ordinary occurrence, during the winter season, in cold-blooded animals. Many of these can even endure the freezing process without the loss of their vitality; their activity being restored by the renewal of warmth. Next to this is the condition of those hibernating mammalia, which pass the winter in a state of uninterrupted torpor, and in which the organic functions seem reduced to their lowest possible amount of activity, short of entire stagnation. This reduction is manifested in the slowness of the circulation, the infrequency of the respiratory movements, the low degree of heat sustained, the abatement of the demand for food, and the small amount of carbonic acid, urea, and other excretory products, set free during the persistence of the hibernating state. But there are other hibernating mammals, in which the reduction is less decided, and the torpor less profound; these animals awaking from their repose at long intervals, taking food from the store which they have prepared, and again relapsing into inactivity. And there are others, again, in which it differs but little from ordinary profound sleep, except that the proportion of time passed in the waking state is much less than usual. Further, it is a curious observation of Dr. M. Hall's (loc. cit.), that the ordinary diurnal sleep of certain hibernating mammalia presents, in the reduced activity of the organic functions, an approach to the torpor of their winter state.

Sleep of Plants.—The complete suspension of the *organic* as well as of the *animal* functions during the hibernation of cold-blooded animals corresponds with what has been termed the *winter sleep* of plants. But plants have also what has been called a *diurnal sleep;* and although it is obvious that plants can present no phenomena really analogous to those in which we have defined the sleep of animals to consist, yet there are periodical changes in the condition of their leaves and flowers which are deserving of consideration under this head, especially as affording ing an additional indication that even in the functions of organic life there is a tendency to a more or less decided alternation of activity and quiescence. The parts of plants which exhibit the changes in question, are the *leaves* and the *flowers*. In the former we frequently notice an entire difference in the nocturnal and diurnal aspects of the leaves, which is the result of a periodic change, affecting either the position of the leaf as a whole, or that of the several leaflets of which a compound leaf is formed. The petioles, or stalks of the leaves or leaflets, either bend upwards or downwards; so that the flattened surface of the leaf is either elevated or depressed. This is not a result of simple flaccidity; for, as De Candolle remarks *, the nocturnal position is maintained with the same rigidity and constancy as the diurnal; so that the "sleeping" leaf would be broken, more readily than it could be forced into the position which is proper to it during the day. Eleven different modifications are enumerated by the distinguished botanist just cited, in the manner in which the leaves incline themselves to the stalks on which they grow. Thus, of the entire leaves which exhibit this phenomenon, some sleep face to face, others back to back,

* Physiologie Végétale, p. 855.

others fold in at the sides so as to embrace the stem or to protect the flower which arises from their axil. It is rare to see a movement of the whole of a compound leaf, when its individual portions fold together; such a movement is seen, however, in the *Mimosæ*. The variety of positions assumed in sleep by the subdivisions of compound leaves is very considerable, and need not be here enumerated: the phenomenon is best exhibited by the *Leguminosæ* and the *Oxalideæ*.

Of the causes of this phenomenon, little can be definitely stated. They are not to be looked for solely in the operation of external physical agents, such as light, heat, and moisture; for it can be easily shown that the changes in question cannot be thus accounted for, without attributing to the plants by which it is exhibited a tendency to such periodical manifestations inherent in their own constitution. Thus, when sensitive plants are confined in a dark room, their leaflets periodically fold and open as usual; the periods, however, being somewhat lengthened. On the other hand, when exposed to continued light, the periodical folding and unfolding still occurs, but the periods are shortened. And when the plants are exposed to strong lamplight by night, and excluded from all light by day, their periods of sleep become extremely irregular for a time, but in the end the plants generally close their leaves during the day and open them at night. No such modifications can be induced, however, in the *Oxalideæ;* their periods of opening and closing their leaves being unaltered by light, darkness, or by the disturbance of the natural sequence of the two. In the same manner it may be proved that these movements cannot be laid to the account of changes of temperature; for it appears from the experiments of De Candolle, that they continue to take place in plants exposed to various degrees of temperature, as well as in those left in air, provided that the heat or cold be not sufficient to injure the health of the plants. And by the same method of exclusion, they can be shown not to be dependent upon variations in the amount of circumambient moisture; since they continue equally well, *cæteris paribus*, when plants are kept in stoves the humidity of whose atmosphere is uniform, and in some cases even when the plants are entirely immersed in water. We must conclude, then, that although the exact time of the occurrence of the phenomenon may be liable to modification from the influence of external agents, its performance is essentially independent of them, aud must be referred to causes inherent in the plant itself.

The periodical closing of *flowers* is a change which is obviously analogous to the sleep of leaves. Many flowers only expand themselves once, and speedily wither. Even in this case, however, there is often considerable regularity in the time of expansion, indicating periodicity. But in the flowers which remain fresh for some days, some degree of alternation between closure and expansion may be generally discerned. There is no definite relation, however, between the sleep of flowers and that of leaves; for they may be united in the same individuals, or be exhibited separately in different species of the same genus. Among other curious examples which show the absence of connection between the two classes of phenomena, is one cited by De Candolle from Berthollet; the subject of it being an Acacia cultivated in the garden at Orotava, in which the leaves closed at sunset, but the flowers then expanded, their numerous stamens raising themselves up like tufts of feathers, so as to become conspicuous; whilst in the morning, when the leaflets assumed their diurnal position, the filaments relaxed so that the bunches of stamens gave to the flowers the appearance of floss-silk, and the flowers themselves partly closed together.

It has been ascertained by Meyen, that, by the action of artificial light and darkness, the usual hours for opening and closing may be changed in flowers as well as in leaves. Thus he found that after passing two days in a room from which external light was excluded, but which was lighted by four Argand lamps, the flowers of *Ipomœa purpurea*, which naturally open during the night, expanded in the morning; whilst those of *Oxalis tetraphylla*, at the end of the fourth day of artificial illumination, opened in the evening, instead of at their usual morning hour.

Periodicity of Sleep. — There can be little doubt that a tendency to occasional repose is inherent in the constitution of every animal possessed of a sensorial apparatus; and that this disposition is so arranged as to correspond in its periodical recurrence with the diurnal revolution of the earth. Although we are accustomed to think that "night is the time for sleep," and although, in our own case and in that of most other animals, darkness and silence favour repose, yet it must be borne in mind that there are many tribes of animals whose period of activity is the very same with that during which most others are wrapped in slumber. Thus, among lepidopterous insects, we find the activity of the greater part of the butterflies to be diurnal, that of the sphinges to be crepuscular, and that of the moths to be nocturnal. So among the insectivorous birds, we find the diurnal swallow replaced during the night by the goatsucker (or night-jar); whilst the insectivorous bats are most active during twilight. Among the raptorial birds, again, we find the whole tribe of owls, with only one or two exceptions, to be either nocturnal or crepuscular in their activity. And among carnivorous animals we meet with a similar diversity. As a general rule, the vegetable-feeders of all tribes are diurnal in their activity, taking their repose at night. The nocturnal predaceous animals take their repose during the day; and those whose period of activity is the twilight, sleep partly by night and partly by day.

Notwithstanding this variety as to the periods of sleep and activity, the complete cycle in every case is fulfilled in twenty-four hours; and this uniformity in their recurrence would seem to indicate either an *entire* and invariable dependence on external agencies, or else a periodical tendency to sleep, inherent in the animal kingdom, and corresponding with the cycle of day and night. The experience of the human species seems to be decisive in favour of the latter view.

There is, among all tribes of mankind, a general uniformity in the periods of slumber and activity, which is scarcely inferior to that observable among the lower animals; yet we find reason to believe that this periodicity is a law of our own organic constitution, for it is quite certain that it cannot be seriously departed from without injury to the system, and that, even where light and warmth are continuous through the whole range of the twenty-four hours (as during the summer in arctic regions), the same periodical desire for sleep manifests itself, resistance to which is prejudicial to the health. As Dr. Whewell justly remarks* — "No one can doubt that the inclination to food and sleep is periodical, or can maintain, with any plausibility, that the period may be lengthened or shortened without limit. We may be tolerably certain that a constantly-recurring period of forty-eight hours would be too long for one day of employment and one period of sleep, with our present faculties; and all whose bodies and minds are tolerably active will probably agree, that, independently of habit, a perpetual alternation of eight hours up and four in bed would employ the human powers less advantageously and agreeably than an alternation of sixteen and eight." We may remark, however, that when the habit has been once acquired, the *shortening* of the cycle is probably not so injurious as its *extension*. We know by experience that the habitual attempt to sustain an uninterrupted activity during more than sixteen or eighteen hours at a time, is either unsuccessful, or, if successful, is very wearing to the system. On the other hand, the experience of seamen who kept "watch and watch" during long voyages without any obvious injury to their health, indicates that if the due amount of sleep be obtained within every twenty-four hours, the division of the cycle is not attended with any prejudicial effect. On the whole, we may conclude with Dr. Whewell, that, "when we have subtracted from the daily cycle of the employments of men and animals, that which is to be set down to the account of habits acquired, and that which is occasioned by extraneous causes, there still remains a periodical character, and a period of a certain length, which coincides with, or at any rate easily accommodates itself to, the duration of the earth's revolution.

Causes of Sleep. — The most potent of all the causes of sleep, which is capable of acting by itself, when in sufficient intensity, in opposition to the most powerful influences tending to the continuance of wakefulness, is the condition of the nervous system induced by its protracted functional activity. Sleep may thus come on in the midst of the roar of cannon, and this not merely in persons accustomed to the noise, but in those who have never previously experienced it. Thus it is on record that during the heat of the battle of the Nile, some of the boys who were over-fatigued fell asleep on the deck. We have known a listener to an orchestral performance drop off in slumber during the noisiest part of the grand finale. Again, the continued demand for muscular activity is not incompatible with the access of sleep. During fatiguing marches, as in the retreat to Corunna, it has been repeatedly noticed that whole battalions of infantry have slumbered whilst in motion; muleteers frequently sleep on their mules, coachmen on their boxes, and post-boys on their horses; and factory children, before the shortening of the hours of work, were often known to fall asleep whilst attending to their machines. Bodily pain, again, yields before the imperative demand occasioned by the continued exhaustion of the powers of the sensorial centres. Of this the medical practitioner has frequent illustrations. It is well known, too, that the North American Indians, when at the stake of torture, will go to sleep on the least remission of agony, and will slumber until the fire is applied to awaken them. It is related that Damiens slept during his protracted tortures upon the rack; and that this having been prevented by the constant renewal of fresh torments, he spoke of the want of sleep, a little before the termination of his existence, as the most dreadful of all the sufferings he had endured. That the strongest voluntary determination to remain awake is forced to give way to the demand for sleep produced by the exhaustion of nervous power, must be within the experience of every one.

It does not appear to be of any consequence whether this exhaustion is produced by the active exercise of volition, emotion, reflection, or simple sensation. In all alike the sensorial centres must participate; by all alike, therefore, must their nervous substance be subjected to that disintegration which cannot proceed beyond a certain point without either being repaired by sleep, or producing a state of exhaustion which becomes fatal. Nevertheless, we find that the involuntary continuance of mental activity is unfavourable to access of sleep, so as to oppose the action of other predisposing influences; and such persistence will be found to be especially difficult to check in cases in which the *feelings* are concerned. The activity of the purely *intellectual* operations, which can be suspended at any moment, provided the feelings be not interested in their continuance, predisposes to sleep instead of preventing it. But the *desire* to work out a result, or to complete the survey of a subject, is an *emotional* state which induces restlessness, remaining active until it is gratified. So, again, anxiety or distress is a most frequent cause of wakefulness; the ex-

* Bridgewater Treatise, p. 40.

citement of the feelings keeping up a *forced* state of mental activity, which no voluntary effort can subdue. The state of *suspense* is in most persons more difficult to bear with equanimity, and is more opposed to the access of sleep, by the continual perturbation which it induces, than the greatest joy or the direst calamity when certainty has been attained. Thus it is a common observation that criminals under sentence of death sleep badly so long as they entertain any hopes of a reprieve; but as soon as they are satisfied that their sentence will be certainly carried into execution, they usually sleep more soundly,—and this even on the very last night of their lives. That the continued excitement of the feelings, whilst producing an indisposition to sleep, really occasions as great a demand for it in the system as is produced by the most active exercise of the intellectual powers, is evident from the very exhausting effects of its protraction; which necessitate a long period of tranquillity for restoration to health.

Among the most powerful of the predisposing causes to sleep, is the *absence* of sensorial impressions: thus darkness and silence usually conduce to repose; and the cessation of the sense of muscular effort, which takes place when we assume a position that is sustained without it, frequently acts as the complement of all other influences. There are cases, however, in which the continuance of an accustomed sound is necessary instead of positive silence, the cessation of the sound being a complete preventive of sleep. Thus it happens that persons living in the neighbourhood of the noisiest mills or forges cannot sleep elsewhere; and when, to induce repose in illness, the mill or the forge has been stopped, the cessation of the sound only occasions more obstinate wakefulness. Such instances, perhaps, fall within the next category of predisposing causes,—namely the *monotonous repetition* of sensorial impressions. Every one knows how efficacious a provocative of sleep is the droning voice of a heavy reader, especially when his subject is equally prosaic. The ripple of the calm ocean upon the shore, the murmur of a rivulet, the sound of a distant waterfall, the rustling of foliage, the hum of bees, and similar monotonous impressions upon the auditory sense, are usually found to induce sleep; and Boerhaave relates, that being desirous of procuring sleep for one of his patients troubled with obstinate insomnia, he directed a brass pan to be so placed as to receive a succession of drops of water, the sound of which had the desired effect. A lulling influence, however, is not universally thus produced; for we have known a case in which sleep was altogether kept away by the sound of dropping water, which seems to have occasioned a state of emotional excitement. Not only is the repetition of auditory impressions provocative of sleep; uniform succession of gentle movements has a similar effect upon the sensorium through the sense of vision. The sleep thus induced, however, is usually characterised by certain peculiarities which will be described hereafter.—The recurrence of impressions received through the sense of touch has the same effect. Thus Dr. Elliotson says*,—"I know a lady who often remains awake in spite of every thing, till her husband very gently rubs her foot; and by asserting to a patient my conviction that the secret of an advertising *hypnologist* whom I allowed to try his art upon the sleepless individual, and which he did for a time successfully, was to make him gently rub some part of his body till he slept, he confessed this to be the fact." The rocking of the infant's cradle, or the gentle swaying of the body backwards and forwards in the arms, are predisposing causes of sleep well known to nurses.

In these and similar cases, the influence of the impressions would seem to be exerted in withdrawing the mind from the consciousness of its own operations, the loss of which, as we shall presently point out, is the transition-step of the passage into complete unconsciousness. The reading of a dull book acts in the same mode. There is a monotony of sensorial impressions, the eyes wandering on from line to line and from page to page, without any mental interest in the sensations received; and if the voluntary effort of attention be intermitted, the thoughts pass off along their own spontaneous train, whilst the sensorial centres are left free to the soporific influence of monotony.

The foregoing are the chief causes of sleep, which operate directly through the sensorial organs themselves. We have now to consider those whose action is indirect, being exerted primarily on the organic functions. Of these the first in order of importance are those which produce increased *pressure* of blood within the vessels of the encephalon. Thus the assumption of the recumbent position operates in this method as a powerful predisponent to sleep, as well as by rendering all muscular effort unnecessary for the maintenance of the position of the body. To this cause again we are probably to attribute, in great part at least, the drowsiness which succeeds a full meal, the pressure within the encephalic vessels being increased by the pressure of the distended stomach upon the vessels of the abdomen; but the circulation of imperfectly assimilated matter in the blood may possibly concur in the production of the result. The influence of pressure is most characteristically seen in cases of gradual effusion of blood or of serum from the vessels of the brain: this at first occasions a state of sopor but little different from profound ordinary sleep; but with the increase of the effusion there is an increase in the depth of the slumber; the patient can no longer be aroused by sensorial impressions which were at first sufficient to re-excite consciousness, and at last complete coma comes on.† A

* Physiology, p. 609.

† Dr. Marshall Hall has advanced the hypothesis, that *ordinary sleep* is the result of congestion of the brain produced by compression of "certain veins,"

moderate degree of warmth favours sleep; perhaps by increasing the energy of the heart's contractions, at the same time that the walls of the vessels are more relaxed than usual, and thus yield to the impulse. A moderate degree of cold usually has the opposite effect, more especially when the cold is sufficient to produce uneasy sensations. But cold of great severity produces drowsiness, sopor, and even complete coma; apparently by producing a contracted state of the superficial vessels of the body, and thus occasioning an increase of sanguineous pressure on the encephalic centres. Again, the circulation of blood charged with narcotic substances through the brain, is one of the most powerful of all hypnotising agencies; and this, again, may produce every gradation of effect, between simple sleep, from which the patient may be easily aroused, and the profoundest coma. One of the most common instances of the operation of this cause, is the production of drowsiness by a deficiency of ventilation; the carbonic acid which accumulates in the blood, when not freely carried off in the air, having the properties of a powerful narcotic.

Phenomena of ordinary Sleep.— The state of perfect sleep is characterised by negative rather than by positive phenomena. As already stated, it essentially consists in the complete suspension of the sensorial powers, and of all those movements in which the nervous system participates, except the simply reflex: with this is conjoined a partial or complete suspension of the functional activity of the cerebrum. According to the more or less potent operation of the soporific causes, will be the degree of insensibility to impressions upon the afferent nerves. No ordinary cause, as we have already shown, is so powerful as previous fatigue. Of the profoundness of the sleep which may result from it, — in combination, perhaps, with two other agents, warmth, and an atmosphere somewhat charged with carbonic acid, — the following remarkable example may be cited from the "Journal of a Naturalist." It may be proper to mention that, the correctness of the statement having been called in question, it was fully confirmed by Mr. Richard Smith, the late senior surgeon of the Bristol Infirmary, under whose care the sufferer had been. "A travelling man, one winter's evening, laid himself down upon the platform of a lime-kiln, placing his feet, probably numbed with cold, upon the heap of stones, newly put on to burn through the night. Sleep overcame him in this situation; the fire gradually rising and increasing, until it ignited the stones upon which his feet were placed. Lulled by the warmth, the man slept on; the fire increased until it burned one foot (which probably was extended over a vent-hole) and part of the leg above the ancle entirely off, consuming that part so effectually, that a cinder-like fragment was alone remaining,—and still the wretch slept on! and in this state was found by the kiln-man in the morning. Insensible to any pain, and ignorant of his misfortune, he attempted to rise and pursue his journey, but missing his shoe requested to have it found; and when he was raised, putting his burnt limb to the ground to support his body, the extremity of his tibia crumbled into fragments, having been calcined into lime. Still he expressed no sense of pain, and probably experienced none, from the gradual operation of the fire, and his own torpidity during the hours his foot was consuming. This poor drover survived his misfortunes in the hospital about a fortnight; but the fire having extended to other parts of his body, recovery was hopeless." It may be added that cases are recorded by medico-legal writers, in which defloration of a virgin, followed by conception, has been effected whilst she was in a state of ordinary sleep, rendered unusually profound by previous fatigue; but such statements are obviously liable to considerable doubt, and scarcely appear entitled to credence.

Besides the suspension of the sensorial functions, however, there is usually a slight diminution in the activity of the functions of organic life. The heart's contractions are less frequent, but the pulse is fuller. So likewise the respiratory movements are diminished in number; but the inspirations are deeper. Less carbonic acid is produced than during a similar bodily inactivity in the waking state. As might be expected from these differences, the amount of heat generated in the body is diminished, and there is much less power of resisting the effects of cold. So remarkable is this abatement, that when the body is exposed to intense cold (as in the well-known attempt of Sir Joseph Banks and Dr. Solander to explore Terra del Fuego), "to sleep is to die." There would seem, too, to be a diminution in the power of resisting other morbific agencies. Thus all authorities agree that *sleeping* in a malarious atmosphere is much more liable to engender the diseases produced by it, than spending the same length of time in the same place, but in the waking state. As a general rule, it would seem that the secreting processes go on with diminished activity during sleep; but to this the cutaneous transpiration is an exception, so that, in debilitated states of the system, a profuse sweating often occurs as soon as the patient falls asleep. From this diminished activity of the organic functions it happens that hunger is not renewed so speedily after sleep as when the same number of hours have been passed in watching; a fact well known to those who are liable to suffer habitually or occasionally from the want of food. In this

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by "a state of contraction of certain muscles of the neck." (See his Observations in Medicine, second series, p. 27.) He does not, however, offer the least proof of this hypothesis, nor does he even name the muscles or veins to which he refers. We presume that the platysma myoides and the external jugular are meant. If so, why should not a slight compression of the vein by any other means have the effect of producing sleep at will?

respect, then, even the ordinary sleep of the warm-blooded animal may be regarded as an incipient hybernation. Some writers have spoken of the organic functions as performed with *increased* activity during sleep; a doctrine so inconsistent with obvious facts, that it could never have been sustained except on the basis of a preconceived idea with regard to the antagonism between the relative activity of the functions of organic and animal life, which idea is in itself fallacious. The actual renovation of the nervous and muscular tissues by the nutritive processes, probably takes place with peculiar energy during the functional inactivity of those parts; but the preparation of the nutritive materials, which is the office of the digestive and assimilative apparatus, seems to go on more slowly during sleep; and it is quite certain that less oxygen is then taken into the system, and less carbonic acid generated and set free.

The *access* of sleep is sometimes quite sudden; the individual passing at once from a state of mental activity to one of complete torpor. More generally, however, it is gradual; and is marked by phenomena which are particularly worthy of attention. "While the mind remains poised, as it were, between sleep and the opposite condition," says Dr. Macnish*, "it is pervaded by a strange confusion, which almost amounts to wild delirium; the ideas dissolve their connection from it, one by one; those which remain longest behind are faint, visionary, and indistinct; and its own essence becomes so vague and diluted, that it melts away in the nothingness of slumber; as the morning vapours are blended with the surrounding air by the solar heat." In this passage there is an attempt made to depict the result of the loss of that power of voluntary control over the current of thought, the possession of which is the especial characteristic of the human mind in its state of normal activity. It is the complete suspension of this power, as we shall presently see, which, taken in connection with the entire want of sensibility to external objects, constitutes the state of dreaming; and the same suspension, occurring before the mind is altogether withdrawn from connection with the external world, constitutes that curious intermediate state betwixt sleeping and waking, which may readily pass into either condition. Thus, if the torpor of the sensorial centres be allowed to increase, sleep is produced; but if it be dissipated by some sensory impression of unusual strength, wakefulness is brought back again, a dreamy impression remaining, both of what had been passing in the mind itself, and of that which had been taking place around. Now, it appears to be by suspending the mind's attention to its own proceedings, and by drawing off the attention of the sensorium from all other impressions upon the organs of sense, that the monotonous sensations already referred to favour the access of sleep. And it may be further affirmed that all the successful plans for voluntarily producing sleep have some such *modus operandi*; their success being dependent upon the intentional fixation of the thoughts upon some one class of sensory impressions (as in the method of Mr. Gardner), or upon some very simple and uniform mental process (such as counting, repeating a French or Greek verb, &c.); and when the attention has been once thus fixed, the monotony of the impression serves to retain it there, so that it abandons, as it were, all control over its operations, and allows itself to be gradually wrapped in repose under the influence of that continued recurrence of similar impressions, which seems even more potent as a soporific than the suspension of *all* sensational stimuli.

The gradual loss of consciousness and of voluntary control over the muscular system during the invasion of sleep is thus described by Dr. Macnish:—"Previous to the accession of sleep, a feeling of universal lassitude prevails; this sensation heralds in the phenomena of slumber, and exhibits itself in yawning, heaviness of the eyes, indifference to surrounding objects, and all the characteristics of fatigue. If the person be seated, his head nods and droops, and, in all cases, the muscles become relaxed, and the limbs thrown into that state most favourable for complete muscular inaction. The lying position is, consequently, the best adapted for sleep, and the one which is intuitively adopted for the purpose. The organs of the senses do not relapse into simultaneous repose, but suspend their respective functions gradually and successively; sight, taste, smell, hearing, and touch, parting with sensation in the order in which they here stand, and gliding insensibly away. In the same manner the muscles do not become simultaneously relaxed; those of the limbs giving way first, then those of the neck, and lastly the muscles of the spine. Nor do the external senses, on awaking, recover all at once their usual vigour; we, for some seconds, neither hear, nor see, nor smell, nor taste, nor touch, with our usual acuteness. Ordinary sights dazzle our eyes; ordinary sounds confuse our ears; ordinary odours, tastes, and sensations, our nose, our tongue, and our touch: they awake successively, one after another, and not in the same instant." *

The power of being *aroused* by impressions made upon the organs of sense, is, as already remarked, one of the chief distinctions between *sleep* and *stupor*. The strength of the impression requisite to produce this effect depends upon two circumstances, which require separate consideration: first, the profoundness of the slumber; and, second, the relation of the impression to the habitual condition of the mind. It is a familiar fact that most persons are much more easily aroused towards the morning, when the slumbers are lighter, than they are during the early part of the night, when the sleep is more profound. In fact, the spontaneous awakening which takes place when our repose has been sufficient for the restoration of mental

* Philosophy of Sleep, p. 21.

* Op. cit. p. 22.

vigour, may generally be traced to some sensory impression of a trivial nature, such as the striking of a clock, which would have produced no effect at a previous time. Some persons, however, always sleep so heavily, that they require a strong impression to arouse them, even when they have had an ample allowance of repose. It is through the hearing and the touch that the awakening impressions are ordinarily conveyed; but either of the other senses may serve as their channel. Thus, although the closure of the eyelids destroys the acuteness of the perception of light, the eyelids are sufficiently transparent to allow of an impression being made by a light of moderate intensity; so that those who sleep in a room whose window has an eastern aspect, and is not furnished with sufficient means of excluding the sun's rays, are liable to be aroused by their ingress some time before the natural amount of repose has been taken. So, again, the sleeper may be awakened by unusual odours; thus the inmates of a burning house are sometimes first aroused by the smell of fire. The introduction of substances possessing a strong taste into the mouth, will also usually put an end to the state of slumber; but when the slumber is very profound, such substances may be received, and even swallowed, without the sleeper being thereby awakened.

The variety of modes in which the operation of sensory impressions on the sleeper is modified by the previous habitual state of mind, is one of the most remarkable points of the whole subject. The general rule is, that habitual impressions of any kind have much less effect in arousing the slumberer, than those of a new or unaccustomed character. An amusing instance of this kind has been related to the author, which, even if not literally true, serves extremely well as an illustration of what is unquestionably the ordinary fact. A gentleman who had taken his passage on board a ship of war, was aroused on the first morning by the report of the morning gun, which chanced to be fired just above his berth; the shock was so violent, as to cause him to jump out of bed. On the second morning he was again awoke, but this time he merely started and sat up in bed; on the third morning the report had simply the effect of causing him to open his eyes for a moment, and turn in his bed: on the fourth morning it ceased to affect him at all, and his slumbers continued to be undisturbed by the report as long as he remained on board. It often happens that sleep is terminated by the *cessation* of an accustomed sound, especially if this be one whose monotony or continuous repetition had been the original inducement to repose. Thus, a person who has been read or preached to sleep, will awake, if his slumber be not very profound, on the cessation of the voice; and a naval officer, sleeping beneath the measured tread of the watch on deck, will awake if that tread be suspended. In this latter case, the influence of the simple cessation of the impression will be augmented by the circumstance next to be alluded to, which has received too little attention from writers on this subject, but which is of peculiar interest both in a physiological and psychological point of view, and is practically familiar to almost every one.

This is, that the influence of sensory impressions is greatly modified by our habitual state of mind in regard to them. Thus, if we are accustomed to *attend* to these impressions, and our perception of them is thus *increased* in acuteness, we are much more easily aroused by them than by others which are in themselves much stronger, but of which we have been accustomed to entertain an utter disregard. Thus, most sleepers are aroused by the sound of their own names uttered in a low tone, when it requires a much louder sound of a different description to produce any manifestation of consciousness. The same thing is seen in comatose states; a patient being often capable of being momentarily aroused by shouting his name into his ear, when no other sound produces the least effect. The following circumstance, communicated to the author by a naval officer of high rank, is a most apposite illustration of this principle. When a young man, he was serving as signal-lieutenant under Lord Hood, at the time when the French fleet was confined in Toulon harbour; and being desirous of obtaining the favourable notice of his commander, he devoted himself to his duty — that of watching for signals made by the look-out frigates — with the greatest energy and perseverance, often remaining on deck nineteen hours out of the twenty-four, with his attention constantly directed towards this one object. During the few hours which he spent in repose, his sleep was so profound, that no noise of an ordinary kind, however loud, would awake him; and it used to be a favourite amusement with his comrades, to try various experiments devised to test the soundness of his sleep. But if the word "signal" was even whispered in his ear, he was instantly aroused, and fit for immediate duty.

It is not requisite, however, that the sound should be one habitually attended to during the hours of watchfulness; for it is sufficient if it be one on which the attention has been fixed as that at which the slumberer is to arouse himself. Thus the medical man, even in his first profound sleep after a fatiguing day's work, is aroused by the first stroke of the clapper of his night-bell; and to those who are accustomed to rise every morning at the sound of an alarum-clock, the frequency and regularity of the occurrence do not diminish, but rather increase, the readiness with which it produces its effect, provided that the warning be promptly obeyed. On this usually depends the efficiency of the awakening sound; if it be disregarded as a thing to which there is no occasion to give heed, it very soon ceases to produce any effect, the entire peal not being sufficient to awake the sleeper; whilst, on the other hand, the first stroke is enough to break the repose of him who is impressed with the effectual desire of profiting by the warning. And thus it may happen that, of two persons in the same room, either shall be at once aroused by a sound which produces no disturbance in the slumbers of the other.— The influence of habitual attention is shown as much in the effect produced by the cessation, as in that of the occurrence, of sensory impressions. Thus in the case of the naval officer aroused by the suspension of the measured tread of the watch over his head, the knowledge possessed during the waking state that this suspension is either an act of negligence which requires notice, or indicates some unusual occurrence, doubtless augments the effect which the discontinuance of the sound would of itself produce.

Putting aside the awakening influence of external impressions, the period of natural termination of the slumber is greatly influenced by habit. Thus, many persons who are accustomed to rise at a particular hour, wake regularly at that hour, whether they have gone to rest early or late ; so that the act of spontaneously awakening is no proof that the desirable amount of repose has been obtained. But what is more remarkable is, that many individuals have the power of determining, at the time of going to rest, the hour at which they shall rise, so as to awake from a profound sleep at the precise time fixed upon. In others, however, the desire to rise at a particular hour only induces a state of restlessness throughout the night, destroying the soundness of the slumbers: the individual awakes many times in the night, with the belief that the hour is past, and very possibly oversleeps it after all, the system being worn out by the need of repose.

The *Amount of sleep* required by man is affected by many conditions, especially *age*, *temperament*, *habit*, and *previous exhaustion;* so that no general rule can be laid down upon the subject. The condition of the fœtus in utero may be regarded as one of continual slumber ; the energy of the organic functions being entirely directed to the building-up of the organism, whilst the apparatus of animal life is completely secluded from all the stimuli which could arouse it into activity. On its first entrance into the world, the infant continues to pass the greater part of its time in slumber; and this is particularly to be noticed in cases of premature birth,—the seven months' child seeming to awake only for the purpose of receiving food, and giving but little heed to any external objects when its internal cravings are satisfied; and even the eight months' infant being considerably less alive to sensory impressions, than one born at the full time. During the whole period of infancy and childhood, it is necessary for the development of the body that the *constructive* operations should be more energetic than the *destructive;* and, accordingly, we find that the period of sleep, during which the former take place without hindrance, is longer in proportion to the waking state, during which the latter are in play, than it is when full growth has been obtained.*

As age advances, the necessity for very rapid nutrition gradually diminishes, in consequence of the progressive approach to complete development ; and when the adult period has been attained, it is not requisite that the *constructive* processes should do more than balance the *destructive*. The amount of sleep requisite for this purpose, therefore, gradually diminishes, until it is reduced to (at most) one-third of the cycle of twenty-four hours. It is to be noticed that the sleep of children and young persons is not only longer than that of adults, but is also more profound. On the other hand, as age advances, and the bodily and mental activity of the waking state decreases, a smaller amount of sleep suffices ; or, if the slumber be protracted, it is usually less deep and refreshing. It may be noticed, however, that *very* old persons usually pass a large proportion of their time in sleep, or rather in dozing ; as if, in consequence of the want of energy of their nutritive operations, a very long period of repose is necessary to repair the waste which takes place during their short period of activity. It is stated† that " the celebrated De Moivre slept twenty hours out of the twenty-four ; and Thomas Parr latterly slept away by far the greater part of his existence." The repose of the aged is most apt to take place immediately after taking food ; while they solicit it in vain at that period at which, during the former years of their lives, they had been accustomed to enjoy it.

The amount of sleep, again, is much affected by *temperament*. It will generally be found that a plethoric habit of body, sustained by full diet, predisposes to sleep, provided the digestive powers be in a vigorous condition. Such persons frequently pass nine or ten hours in slumber, and maintain that they cannot be adequately refreshed by less. On the other hand, thin wiry people, in whom the " nervous" temperament predominates, usually take comparatively little sleep, notwithstanding the greater activity of their nervous system when they are awake ; but their slumber, while it lasts, is generally very deep. Persons of "lymphatic" temperament, heavy

* It is to be remembered, when we compare the condition of the nutritive operations during the period of growth, and after the complete development of the organism, that it is not in the mere amount of *accretion* that the difference consists. This would be the case if the new matter were merely *added* to the old, as in the formation of a new layer of wood in an exogenous stem. The growth of the animal fabric requires a continual new development of every part of it, involving a constant change in its materials ; and thus we see that the amount of food required by children, and the quantity of urea, and other products of the disintegration of the tissues set free in their excretions, bear a much larger proportion to those of the adult, than would be inferred from the relative bulk of the body at the two periods, and from its rate of increase during the former.

† Macnish, op. cit. p. 37.

passionless people, who may be said to live very slowly, are usually great sleepers; but this rather because, through the dullness of their perceptions, they are less easily kept awake by sensorial or mental excitement, than because they really require a prolonged cessation of activity. As they are half asleep during the waking state, so would it appear that the constructive operations must be far from active while they are asleep,—so little do they seem restored by the repose.

The amount of sleep, *cæteris paribus*, required by individuals, is very greatly influenced by *habit;* and, contrary to what we might anticipate, we find that the briefest sleepers have usually been men of the greatest mental activity. Thus Frederick the Great and John Hunter are said to have only required five hours' sleep out of the twenty-four. General Elliot, celebrated for his defence of Gibraltar, is recorded not to have slept more than four hours out of the twenty-four.* Sir Gilbert Blane states † that General Pichegru informed him that, " in the course of his active campaigns, he had for a whole year not more than one hour of sleep, on an average, in twenty-four hours." We suspect that if he had said " one hour of sleep at a time," he would have been nearer the truth. This we believe to have been the case with regard to the Duke of Wellington during the Peninsular campaigns. Dr. Elliotson says ‡, " I heard Baxter, the coachmaker, declare that he never took more than three hours' sleep during the most active period of his life." We doubt if it would be possible for any one to sustain a life of vigorous exertion with a smaller allowance than this.

The influence of habit is further shown in producing an aptitude for repose, or a readiness to wake, at particular periods. Thus, if a man is accustomed to go to rest at ten o'clock, and to rise at six, he will probably awake at six, even if he have not fallen asleep until twelve. And in like manner, if the morning sleep have been unusually protracted, the desire for sleep will probably return at the accustomed hour in the evening. The influence of habit is further exerted in producing an aptitude for sleep whenever the opportunity is afforded. Thus, the celebrated pedestrian Capt. Barclay, when accomplishing his extraordinary feat of walking 1000 miles in as many successive hours, obtained at last such a mastery over himself that he fell asleep the instant he lay down. And the sleep of soldiers, sailors, and others, who may be prevented from obtaining regular periods of repose, but are obliged to take their rest at short intervals, may be almost said to come at command; nothing more being necessary to induce it than the placing the body in an easy position, and the closure of the eyes. On the other hand, habit favors the protraction of sleep. This was the case with Quin, the celebrated actor, who could slumber for twenty-four hours successively; and with Dr. Reid, the metaphysician, who could take as much food, and afterwards as much sleep, as were sufficient for two days.

It is needless to dwell upon the obvious fact, that, other things being equal, the amount of sleep required by man is proportional to the amount of mental exertion put forth during the waking hours; since this is an obvious result of what has been laid down as the cause of the demand for sleep. It may be remarked, however, that we must not measure the *amount* of sleep by its *duration* alone; since its *intensity* is a matter of equal importance. The light slumber which is disturbed by the slightest sounds, cannot be as renovating as the profound sopor of those whom no ordinary noise will awake.

There are certain states of the nervous system in which there is an *entire absence of sleep;* and this may continue for many days, or even weeks or months. Insomnia is, for instance, one of the characteristics of acute mania, and may also exist in various forms of monomania. It is usually, also, one of the symptoms of incipient meningeal inflammation. And it may constitute a specific disease in itself. In all these cases, however, the preponderance of the *destructive* processes over the *constructive* manifests itself, sooner or later, in the exhaustion of the mental and bodily powers. Thus mania, when prolonged or frequently occurring, subsides into dementia. When meningitis (or rather inflammation of the surface of the hemispheric ganglia) is fully developed, a rapid disintegration of nervous matter takes place, as indicated by the large amount of alkaline phosphates in the urine.* The same would probably be detected in cases of idiopathic insomnia; which state, if it continue for any length of time, is sure to be followed by a great sense of wretchedness and prostration, frequently accompanied by continual restlessness. Such effects, too, in a less aggravated degree, result from habitual *deficiency* of sleep; whether this results from emotional excitement, which keeps repose at bay, or from a voluntary determination to keep the intellect in activity. This is a very common occurrence among industrious students, who, with a laudable desire for distinction, allow themselves less than the needed quantum of repose. Headache, tension, heat, throbbing, and various other unpleasant sensations in the head, give warning that the brain is being overtasked; and if this warning be not taken, sleep, which it was at first difficult to resist, becomes even more difficult to obtain; a state of general restlessness and feverish excitement are induced; and if, in spite of this, the effort be continued, serious consequences, in the form of cerebral inflammation, apoplexy, paralysis, fever, insanity, or loss of mental power, more or less complete, are nearly certain to be induced. Some individuals can sustain such an effort much longer than others, but it is a great mistake to suppose that they are not

* Macnish, op. cit. p. 34.
† Medical Logic, p. 83.
‡ Physiology, p. 601.

* See Dr. Bence Jones in Phil. Trans. 1846.

equally injured by it; in fact, being possessed with the belief that they are not suffering from the exertion, they frequently protract it until a sudden and complete prostration gives a fearful demonstration of the cumulative effects of the injurious course in which they have been persevering. Those, consequently, who are earlier forced to give way, are frequently capable of accomplishing more in the end.

In regard to the degree of *protraction* of sleep which is consistent with a healthy state of the system in other respects, it is difficult to speak with certainty. Of the numerous well-authenticated instances on record*, in which sleep has been continuously prolonged for many days or even weeks, it is enough here to state that they cannot be regarded as examples of natural sleep; the state of such persons being more closely allied to hysteric coma. An unusual tendency to proper sleep generally indicates a congested state of the brain, tending to apoplexy; and it has been stated that apoplexy has been actually induced by the experimental attempts to ascertain how large a proportion of the diurnal cycle might be spent in sleep. This effect may be readily explained, if we regard it as a general law of the capillary circulation, that its rate is increased by functional activity, and diminished by inactivity; for whilst congestion of the brain arising from other causes will tend to produce sleep, through the augmented pressure it occasions, mental inactivity, if encouraged and persisted in, will itself tend to produce congestion.

Thus, on either side, inattention to the dictates of Nature in respect to the amount of sleep required for the renovation of the system, becomes a source of disease, and should therefore be carefully avoided.

DREAMING.

We have hitherto spoken of sleep in its most complete or profound form,—that is, the state of complete unconsciousness. But with the absence of consciousness of external things, there may be a state of mental activity, of which we are more or less distinctly conscious at the time, and of which our subsequent remembrance in the waking state also varies in completeness: the impression being sometimes vivid, definite, and enduring; sometimes shadowy and evanescent; sometimes not amounting to more than the feeling that we have dreamed; and sometimes not even this being preserved, notwithstanding that there may be positive assurance that the sleep has been thus disturbed. This state, known as *dreaming*, is one of the highest interest to the psychologist; but the limits imposed upon us forbid our doing more than enumerate its leading phenomena.

The chief feature of the state of dreaming appears to be, that there is an entire *absence of voluntary control* over the current of thought; so that the principle of *suggestion*—one thought calling up another, according to the laws of association—has unlimited operation. Sometimes the train of thought thus carried on is remarkably consistent. We witness scenes that have occurred during our waking hours, and seem to hear, see, move, talk, and perform all the actions of life. We may experience every kind of mental emotion, and may even compare, reason, judge, and will, during our sleep; and our reasoning processes have frequently a remarkable clearness and completeness,—the data on which they are founded being supposed to be accurate. This consistency is usually the greatest, when the mind simply takes up a train of thought on which it had been engaged during the waking hours, not long previously; and it may even happen that, in consequence of the freedom from distraction occasioned by the suspension of ordinary sensations, the intellectual operations may be carried on during sleep with uncommon vigour and success. Thus, to name only two instances, Condorcet saw, in his dreams, the final steps of a difficult calculation, which had puzzled him during the day; and Condillac states that, when engaged with his "Cours d'Etude," he frequently developed and finished a subject in his dreams, which he had broken off before retiring to rest.

The imagination, equally with the reasoning processes, sometimes moves in a consistent course. Thus, Dr. Good relates the case of a friend who composed a little ode of about six stanzas, and set the same to agreeable music, in his sleep, the impression remaining so vividly that he was able to write down both the words and music on awaking in the morning; and Coleridge relates of himself that his fragment, entitled "Kubla Khan," was composed during sleep, which had come upon him whilst reading the passage in "Purchas's Pilgrimage" on which the poetical description is founded, and was written down immediately on awaking. The images, he says, "rose up before him as things, with a parallel production of the correspondent expressions, without any sensation or consciousness of effort." It would seem necessary, in most cases of this kind, that the results should be committed to paper immediately on waking, before the train of thought, continued from the dream, has been disturbed by any other. Thus, Coleridge tells us that, after having written for some little time, he was interrupted by a person on business, who continued with him above an hour; and on the departure of his visitor, he found, to his surprise and mortification, that "though he still retained some vague and dim recollection of the general purport of the vision, yet, with the exception of some eight or ten scattered lines and images, all the rest had passed away like the images on the surface of a stream into which a stone had been cast; but, alas! without the after-restoration of the latter." In other cases, a strong general impression of what has passed through the mind in sleep may remain on waking, without power of recalling the particulars. This was the case in the well-known instance of the musician Tartini, to whom the

* Such, for example, as that of Samuel Chilton (Phil. Trans., 1694), and that of Mary Lyall (Trans. of Roy. Soc. of Edinb., 1818).

arch-fiend appeared in his sleep, and was challenged by him to a trial of skill: the dreamer lay entranced by the transcendent performance of his visitor, which surpassed anything he had ever heard or conceived; on awaking, however, he could not reproduce the succession of notes, although he immediately seized his violin, and endeavoured to do so; but, under the strong general impression of what he had heard, he produced a new composition, which retains the name of the "Devil's Sonata."

But, although dreams *may* possess a remarkable coherence, whether as regards processses of reasoning, or the new combinations of the imagination, the general fact is, that such coherence is altogether wanting, and that there is a complete incongruousness in the thoughts and images which pass through our minds. All probabilities, and even possibilities of "time, place, and circumstance" are violated; the dead pass before us as if alive and well; even the sages of antiquity hold personal converse with us; our friends at the antipodes are brought upon the scene, or we ourselves are conveyed thither, without the least perception of distance; and the strangest combinations of reality and fancy are presented, either as objects passing before our consciousness, or as affecting our own condition. But of this incongruity we are seldom in the least aware. We are not capable of testing the probability or possibility of the phenomena by our ordinary experience. And, as a consequence of this, nothing surprises us in dreams; the feeling of surprise being the result, and indeed the measure, of our perception of the unlikelihood of a phenomenon. Not only is there usually a want of congruity in the intellectual processes, but a great disturbance in the ordinary play of the emotions. "Thus, in our dreams we may walk on the brink of a precipice, or see ourselves doomed to immediate destruction by the weapon of a foe or the fury of a tempestuous sea, and yet feel not the slightest emotion of fear; though, during the perfect activity of the brain, we may be naturally disposed to the strong manifestation of this feeling. Again, we may see the most extraordinary object or event without surprise, perform the most ruthless crime without compunction, and see what in our waking hours would cause us unmitigated grief, without the smallest feeling of sorrow." * This is, however, by no means uniformly the case. In fact, our emotions in the dreaming state are often highly wrought; and it frequently seems that the excitement of some particular emotion gives the direction to the whole train of thought, and causes it to possess an unusual coherence and probability. This is most remarkable, perhaps, when the emotion in question has greatly occupied the mind in the previous waking hours. Thus, a female, whose husband is at sea, and for whose safety she naturally feels anxious, especially in stormy weather, is very apt to dream of shipwreck and all its attendant circumstances; or, on the other hand, a man in love dreams of his mistress, of married life, and of its various enjoyments. Even here, however, the congruity is frequently interrupted by the intervention of some strange occurrence; the oddity of which may be perceived by the dreamer as being discordant, not with the intellectual but with the emotional state.

* Prof. Wheatstone, quoted in Elliotson's Physiology, p. 621.

In simple dreaming, as there is a loss of voluntary control over the current of thought, so is there an absence of control over the muscular system. Movements expressive of emotions, however, may still take place, and may afford to the by-stander an indication of what is passing in the mind of the dreamer. The indications of fear, horror, or disgust, or of hope, rapture, or desire, — laughter or weeping, smiles or frowns,— may all display themselves, when there is an absolute cessation of all voluntary movements. This is remarkably the case in attacks of *incubus*, or nightmare; in which the dreamer is oppressed by intolerable distress, from which he makes vain attempts to free himself. His distress may be expressed by moans, or by the agitation of his countenance; but none of his fancied efforts are indicated by any respondent movements. This condition may subside into a state of tranquil slumber, or the agitation may increase to such a pitch as to awake the sufferer; and as the first act of the waking state is usually to cry out or kick violently, it has been supposed that the return of volition has been the cause, instead of being the effect, of the cessation of the oppressive dream. There are cases, however, in which the dreamer executes movements in consonance with *ideas* passing through his mind, — such as would, in the waking state, be termed voluntary; but these must be considered as belonging rather to the category of somnambulism than to that of simple dreaming.

The direction of the current of thought in dreaming is often given by impressions on the organs of sense, which influence the mental operations, by calling up associated ideas, without being recognized and perceived as distinct sensations. Thus, Dr. James Gregory, having applied a hot bottle to his feet on going to bed, dreamt that he was walking up Etna and finding the ground intolerably hot. On another occasion, he dreamt of spending a winter at Hudson's Bay, and of suffering much distress from the intense frost; this evidently the consequence of his having thrown off the bed-clothes in his sleep, and of his having been reading, a few days before, a very particular account of the state of the colonies in that country during winter. Dr. Reid, having a badly-dressed blister on his head, dreamt that he was being scalped by Indians; and a man in a damp bed, that he was being dragged through a stream. A gouty man, when beginning to feel his pain in his sleep, may dream he is on the rack before inquisitors. The sound of music may excite delightful dreams. M. Girou de Buzareingues * made some curious experiments on

* Journal de Physiologie, tom. viii.

this point, and directed at pleasure the character of his dreams. In his first experiment, having allowed the back of his head to be uncovered during sleep, he thought he was at a religious ceremony in the open air; the custom of the country in which he lived being to keep the head covered excepting on some rare occurrences, among which was the performance of religious ceremonies. On waking he felt cold at the back of the neck, as he frequently had when present at the real ceremonies. He repeated the experiment in two days, with the same result. In a third experiment, he left his knees uncovered, and dreamt that he was travelling at night in the diligence; and all travellers know, he observes, that it is chiefly at the knees that they feel cold when travelling by that conveyance at night. The very remarkable degree in which this influence of external impressions is exerted, when sleep is being induced by the agency of certain narcotics, will be presently noticed. By the use of the term "external" is here meant that which is external to the mind itself. The dream may originate in impressions derived from any part of the bodily frame. Thus we find that indigestion is a very common cause of nightmare, and that an irritable state of the genital apparatus provokes lascivious dreams. When the external impressions are recognized as *sensations*, and the dreamer's current of thought completely follows their guidance, so that even the meaning of spoken language is appreciated, the condition approximates to that of Somnambulism.

One of the most remarkable of all the peculiarities of the state of dreaming, is the rapidity with which trains of thought pass through the mind; a dream in which a long series of events has seemed to occur, and a multitude of images has been successively raised up, being often certainly known to have occupied but a few minutes or even seconds. This is best seen in those cases in which the dream has obviously originated in some sensory impression, which has also had the effect of arousing the sleeper. A very interesting example of this, in which a similar dream was produced in two individuals, husband and wife, from the same cause, came within the knowledge of the late Dr. James Gregory. It happened when the public mind was much excited in regard to the alarm of French invasion, and the gentleman who was the subject of it was himself a zealous member of the Edinburgh volunteer corps. Whilst asleep, between two and three o'clock in the morning, he dreamt of hearing the signal gun: he was immediately at the Castle, witnessed the proceedings for displaying the signals to alarm the country, and saw and heard a great bustle over the town, from troops and artillery assembling, especially in Princes Street. At this time he was roused by his wife, who awoke in a fright, in consequence of a similar dream, connected with much noise and the landing of the enemy, and concluding with the death of a particular friend of her husband's, who had served with him as a volunteer. The origin of this remarkable occurrence was ascertained, in the morning, to be the noise produced in the room above by the fall of a pair of tongs. How long the dream had continued in this instance is uncertain; evidently not for a period in the least comparable to that required for the actual occurrence of the events that had passed through the mind of each; and it is probable, from many similar cases, that the lady was awoke by the noise rather than by the fright. Thus a gentleman dreamt that he had enlisted as a soldier, joined his regiment, deserted, was apprehended, carried back, tried, condemned to be shot, and at last led out for execution. After all the usual preparations, a gun was fired; he awoke with the report, and found that a noise in an adjoining room had both produced the dream and awoke him. The same feeling of duration, arising out of the number of images passing in succession through the mind, is often experienced when we are well assured that the whole duration of our sleep has not exceeded a few moments. We have known a clergyman fall asleep in his pulpit during the singing of the psalm before sermon, and awake with the conviction that he must have slept for at least an hour, and that the congregation must have been waiting for him; but on referring to his psalm-book, he has been consoled by finding that his slumber has lasted no longer than during the singing of a single line. There would not seem, in fact, to be any limit to the amount of thought which may thus pass through the mind of the dreamer, in an interval so brief as to be scarcely capable of measurement; and this view is confirmed by the circumstance, now well attested, that it is a common occurrence in drowning for the whole previous life of the individual to be presented instantaneously to his view; with its every important incident vividly impressed on his consciousness, just as if all were combined in a picture, every part of which could be taken in at a glance. This, again, is connected with the fact that the operation of the associative principle may reproduce in dreams the remembrance of facts long since forgotten in the waking state. Such, however, is by no means peculiar to the state of dreaming; for in the waking state we often retrace involuntarily and unexpectedly something which we have in vain attempted to recall at will, and which might be said to have passed from our mental grasp.

From the foregoing and other similar facts it has been argued, that *all* our dreams really take place in the act of falling asleep or of awaking; so that even when we fancy that we have been dreaming all night, our unconsciousness has been really complete, except at these momentary intervals. That this doctrine cannot be altogether true is obvious from the fact, that we can frequently detect the character of a dream, and even in some degree trace its progress, by the expression of the sleeper's countenance; so that dreams certainly *may* occupy time, and occur during ordinary sleep. On the other hand, it may be freely admitted that the apparent duration of our dreams does not afford the least measure of the time they have really occupied; and that it is probable that even when our sleep has seemed most disturbed by them, we have really passed a larger portion of the night in a state of complete unconsciousness than the mere impression left by our dreams would allow us to believe. But it has been questioned by some, on the other hand, whether there is ever such a state as that of complete unconsciousness. It is affirmed that the mind *can never* be entirely inactive; and that every body, in fact, does dream throughout the period of sleep, although the dreams may not be remembered in the waking state. This statement is rather based upon the hypothesis with which it commences, than upon any positive facts; and as it requires us to give up the simple teachings of ordinary experience, for the reception of a mere metaphysical dogma, the physiologist need not concern himself with the discussion.

On the whole, it may be said that dreaming indicates that sleep is imperfect; and this view harmonises with the fact that between dreaming and the waking state there are various connecting gradations. Thus, reverie or day-dreaming differs from the dreaming of the sleeper, not so much in the condition of the mind and its instrument the cerebrum, as in that of the sensorium, which is not so completely withdrawn in the former case, as it is in the latter, from the consciousness of external impressions. In sleep, on the other hand, the dreamer may have a consciousness of the unreality of the images that arise in his mind, and may even make a voluntary and successful effort to prolong them if agreeable, or to dissipate them if unpleasing; thus evincing the presence of that power of control over the current of thought, the want of which is one of the best characteristics of ordinary dreaming, as it is also of insanity, and indicating, therefore, an unusual approximation to the vigilant condition.

The action of narcotics on the nervous system presents many curious illustrations of the foregoing statements regarding the nature and phenomena of dreaming. There are some which have the power of inducing every condition intermediate between an unusual activity of the thoughts and a state of complete stupor, according to the dose taken. This is the case to a certain degree with opium; but still more decidedly with the extract of *Cannabis Indica*, a preparation of whch, known under the names of Hachisch and Dawamesc, is much used in the East for the production of a species of agreeable intoxication. The first effect of a dose of this substance is usually to produce a moderate exhilaration of the feelings and an unusual activity of the intellectual powers; but this activity gradually frees itself from voluntary control. The individual feels himself incapable of fixing his attention upon any subject; his thoughts being continually drawn off by a succession of ideas which force themselves (as it were) into his mind, without his being able in the least to trace their origin. These speedily occupy his attention, and present themselves in strange combinations, so as to produce the most fantastic and impossible creations. By a strong effort of the will, however, the original thread of the ideas may still be recovered, and the interlopers driven away. These lucid intervals successively become of shorter duration, and can be less frequently procured by a voluntary effort; for the internal tempest becomes more and more violent, the torrent of disconnected ideas increases in power so as completely to arrest the attention, and the mind is gradually withdrawn altogether from the contemplation of external realities, being engrossed by the consciousness of its own internal workings. There is always preserved, however, a much greater amount of self-consciousness than exists in ordinary dreaming; the condition rather corresponding with that just referred to, in which the sleeper *knows* that he is dreaming. The succession of ideas has at first less of incoherence than in ordinary dreaming, the ideal events not departing so far from possible realities; and the disorder of the mind is at first manifested in errors of sense, in false convictions, or in the predominance of one or more extravagant ideas. These ideas and convictions are generally not altogether of an imaginary character, but are called up by external impressions, which are erroneously interpreted by the perceptive faculties. The error of perception is remarkably shown in regard to time and space; minutes seem hours, hours are prolonged into years, and at last all idea of time seems obliterated, and past and present are confounded together as in ordinary dreaming: and in like manner, streets appear of an interminable length, and the people at the other end seem to be at a vast distance. Still there is a certain consciousness of the deceptive nature of these illusions, which, if the dose be moderate, is never entirely lost.

The effect of a full dose, however, is at last to produce the complete withdrawal of the mind from any distinct comprehension of external things; the power of the will over the current of thought is in like manner suspended, and the condition of the mind becomes the same in all essential particulars with that of the ordinary dreamer; differing in this chiefly, that the feelings are more strongly exerted, and that they still take their tone almost entirely from external impressions. Thus, says M. Moreau*, "It will be entirely dependent on the circumstances in which we are placed, the objects which strike the eyes, the words which fall on our ears, whether the most lively sentiments of gaiety or of sadness shall be produced, or passions of the most opposite nature shall be excited, sometimes with extraordinary violence; for irritation

* Du Hachisch et de l'Aliénation Mentale, Etudes Psychologiques, p. 67.

shall pass rapidly into rage, dislike to hatred, and the desire of vengeance and the calmest affection to the most transporting passion. Fear becomes terror, courage is developed into rashness which nothing checks, and which seems not to be conscious of danger, and the most unfounded doubt or suspicion becomes a certainty. The mind has a tendency to exaggerate everything, and the slightest impulse carries it along. Those who make use of the hachisch in the East, when they wish to give themselves up to the intoxication of the *fantasia*, take great care to withdraw themselves from everything which could give to their delirium a tendency to melancholy, or excite in them anything else than feelings of pleasurable enjoyment. They profit by all the means which the dissolute manners of the East place at their disposal. It is in the midst of the harem, surrounded by their women, under the charm of music and of lascivious dances executed by the Almees, that they enjoy the intoxicating dawamesc; and with the aid of superstition, they find themselves almost transported to the scene of the numberless marvels which the Prophet has collected in his Paradise."*

SOMNAMBULISM.

Our history of sleep would be incomplete without some account of a state which is closely allied to it, though differing from it in several important particulars. The phenomena of somnambulism are so varied, that it is very difficult to frame any definition capable of including them all; and we prefer characterising the state by saying that it may be considered as an *acted dream*,—differing from ordinary dreaming in the two following points. In the first place, the train of thought is more under the direction of sensations derived from without; and, secondly, the muscular system is so completely under the control of the mind, as not merely to give expression to its emotional states, but also to act in respondence to its volitions. As in dreaming, there would seem to be, in true somnambulism, a complete want of voluntary control over the current of thought, but there is not the same degree of mental activity; and in particular the operation of the associative principle is so much more restricted, that there is little or none of that incoherence or incongruity in the ideas brought up, which is so peculiar in ordinary dreaming. On the contrary, reasoning processes are often carried out with extraordinary clearness and correctness; the mind being intently fixed upon them to the exclusion of all other considerations. This *exclusiveness*, indeed, is one of the most remarkable characteristics of the condition. Whilst the attention of the mind remains fixed upon any object, either perceived by the senses or brought up by the act of conception, nothing else is felt. Thus there may be complete insensibility to bodily pain, the somnambulist's whole attention being given to that which is passing within the mind. Yet, in an instant, by directing the attention to the organs of sense, the anæsthesia may be succeeded by the most acute sensibility. So, again, when the attention is fixed upon a certain train of thought, whatever is spoken in harmony with it is heard and appreciated by the somnambulist; but whatever is in discordance with it is entirely disregarded. The character of the intellectual operations partakes of this peculiarity. As just now stated, the reasoning processes are usually accurately and definitely carried on, so that the conclusion will be sound, provided that the data have been correct. Thus, a mathematician will work out a difficult problem, or an orator will make a speech appropriate to a given subject. But the usual defect of the intellectual operations carried on in this condition is, that, owing to their very intensity, the attention is drawn off from the considerations which ought to modify them; and thus it happens that the result is often palpably inconsistent with the teachings of ordinary experience, and will be admitted to be so by the somnambulist when the former are brought to his mind.

The state of somnambulism may pass, on the one hand, into that of ordinary dreaming, so that it is difficult to draw the line between the two. Thus, the ordinary "talking in the sleep" may be referred to one or the other condition, according to the definition of each that we may adopt. In our own arrangement, they fall under the second head: because the vocal movements are expressions of the intellectual processes that are taking place in the mind; and because, in most cases of this kind, the sleep-talker hears and comprehends what is said to him, provided that this harmonises with what is going on within, and will answer rationally, so as to sustain a conversation. Thus, we knew a young lady at school, who frequently began to talk after having been asleep an hour or two; her ideas almost always ran upon the events of the previous day; and if encouraged by leading questions addressed to her, she would give a very distinct and coherent account of them; frequently disclosing her own peccadilloes and those of her school-fellows, and expressing great penitence for the former, whilst she seemed to hesitate about making known the latter. To all ordinary sounds, however, she seemed perfectly insensible. A loud noise would awake her, but

* The celebrated oriental scholar, M. Sylvestre de Sacy, appears to have made it pretty plain that our word *assassin* is derived from *Hachischin*, in the following manner. It is well known that the term was originally employed in Syria, to designate the followers of the "Old Man of the Mountain," who were accustomed to devote themselves with blind obedience to the execution of the orders of their chief, sacrificing themselves or others with equal readiness. Their education tended in every way to impress upon them this duty; and as a reward for its performance, they were promised after death all the sensual pleasures they could imagine,—a foretaste of these being every now and then given to them by intoxicating them with *hachisch*, in the midst of scenes in which everything was provided to gratify their senses. In this manner, a sort of fanaticism was gradually induced, which rendered them fit agents of the murderous designs of their master.

was never perceived in the sleep-talking state; and if the interlocutor addressed to her any questions or observations that did not fall in with her train of thought, they were completely disregarded. By a little adroitness, however, she might be led to talk upon almost any subject; a transition being gradually made from one to another by means of leading questions.

The well-known case of the officer, narrated by Dr. James Gregory, is one of the same intermediate class; rather allied, in our apprehension, to somnambulism than to ordinary dreaming. This gentleman, who served in the expedition to Louisburgh in 1758, was in the habit of *acting* his dreams; and their course could be completely directed by whispering into his ear, especially if this was done by a friend with whose voice he was familiar; so that his companions in the transport were in the constant habit of amusing themselves at his expense. At one time they conducted him through the whole progress of a quarrel, which ended in a duel; and when the parties were supposed to be met, a pistol was put into his hand, which he fired, and was awakened by the report. On another occasion they found him asleep on the top of a locker or bunker in the cabin, when they made him believe he had fallen overboard, and exhorted him to save himself by swimming. He immediately imitated all the motions of swimming. They then told him that a shark was pursuing him, and entreated him to dive for his life. He instantly did so, with such force as to throw himself entirely from the locker upon the cabin-floor, by which he was much bruised, and awakened of course. After the landing of the army at Louisburgh, his friends found him one day asleep in his tent, and evidently much annoyed by the cannonading. They then made him believe that he was engaged, when he expressed great fear, and showed an evident disposition to run away. Against this they remonstrated; but, at the same time, increased his fears, by imitating the groans of the wounded and the dying; and when he asked, as he often did, who was down, they named his particular friends. At last they told him that the man next himself in the line had fallen, when he instantly sprung from his bed, rushed out of the tent, and was roused from his danger and his dream together, by falling over the tent-ropes. After these experiments, he had no distinct recollection of his dreams, but only a confused feeling of oppression and fatigue; and used to tell his friends that he was sure they had been playing some trick upon him. This is another point of conformity with somnambulism; one of whose most distinctive peculiarities it is, that neither the trains of thought nor any of the events of the somnambulistic state are remembered in the ordinary waking condition, though the impression of the feelings strongly excited during that state, is sometimes continued. Both the trains of thought and the events of the somnambulistic state, however, are frequently remembered with the utmost vividness on the recurrence of that state, even at a very distant interval: and of the interval, however long it may have been, there is no consciousness whatever. The same thing, but more rarely, occurs in dreaming; the dreamer sometimes recollecting a previous dream, and even taking up and continuing its thread, although he could not in the least retrace it in his waking state.

A remarkable case of spontaneous somnambulism, which occurred within our own experience, will serve to illustrate many of the most characteristic features of the condition in question. The subject of it was a young lady of highly nervous temperament; and the affection occurred in the course of a long and trying illness, in which almost every form of hysteria, simulating tetanus, epilepsy, coma, and paralysis, had successively presented itself. Although natural somnambulism ordinarily arises out of ordinary sleep, yet in this instance the patient usually passed into the somnambulistic condition from the waking state; the transition being immediately manifested by the peculiar expression of the countenance. In this condition her ideas were at first entirely fixed upon one subject—the death of her only brother, which had occurred some years previously. To this brother she had been very strongly attached; she had nursed him in his last illness; and it was perhaps the return of the anniversary of his death about the time when the somnambulism first occurred, that gave to her thoughts that particular direction. She talked constantly of him, retraced all the circumstances of his illness, and was unconscious of anything that was said to her which had not direct reference to this subject. On one occasion she mistook her sister's husband for her lost brother; imagined that he was come from heaven to visit her; and kept up a long conversation with him under this impression. This conversation was perfectly rational on her side, allowance being made for the fundamental errors of her data. Thus, she begged her supposed brother to pray with her; and on his repeating the Lord's Prayer, she interrupted him after the sentence "forgive us our trespasses," with the remark, "But *you* need not pray thus; *your* sins are already forgiven." Although her eyes were open, she recognised no one in this state, not even her own sister, who, it should be mentioned, had not been at home at the time of her brother's illness.

On another occasion, it happened that, when she passed into this condition, her sister, who was present, was wearing a locket, containing some of their deceased brother's hair. As soon as she perceived this locket, she made a violent snatch at it, and would not be satisfied until she had got it into her own possession, when she began to talk to it in the most endearing and even extravagant terms. Her recognition of this locket, when she did not perceive that her sister was the wearer of it, was a very curious fact, which may be explained in two ways, each of them in accordance with the known laws of somnambulism. Either the concentration of her thoughts on this one subject caused her to remember only that which was *immediately* connected with her brother; and her unconsciousness of the presence of her sister might be due to the absence of the latter at the time of his death, which caused her to be less connected with him in the thoughts of the somnambulist:—or it may have happened that she was directed to this locket by the sense of smell, which is frequently exalted in a very remarkable degree in the somnambulistic state. (See SMELL.) Her feelings were so strongly excited by the possession of the locket, that it was judged prudent to check their continuance; and as she was inaccessible to all entreaties on the subject, force was employed to obtain it from her. She was so determined, however, not to relinquish it, and was so angry at the gentle violence used, that it was found necessary to abandon the attempt; and she became calmer after a time, and at last passed off into ordinary sleep, which was in her case the successor, instead of being (as it usually is) the predecessor, of the somnambulistic state. Before going to sleep, however, she placed the locket under her pillow, remarking, "Now I have hid it safely, and they shall not take it from me." On awaking in the morning, she had not the slightest consciousness of what had passed; but the impression of the excited feelings remained; for she remarked to her sister,—"I cannot tell what it is that makes me feel so; but every time that S—— comes near me, I have a kind of shuddering sensation;"—the individual named being a servant, whose constant attention to her had given rise to a feeling of strong attachment on the side of the invalid, but who had been the chief actor in the scene of the previous evening. This feeling wore off in the course of a day or two. A few days afterwards, the somnambulism again recurred; and being upon her bed at the time, she immediately began to search for the locket under her pillow. In consequence of its having been removed in the interval (in order that she might not, by accidentally finding it, be led to inquire into the cause of its presence there, of which it was thought better to keep her in ignorance), she was unable to find it; at which she expressed great disappointment, and continued feeling for it, with the remark, "It *must* be there; I put it there myself a few minutes ago; and no one can have taken it away." In this state, the presence of S—— renewed her previous feelings of anger; and it was only by sending S—— out of the room that she could be calmed and induced to sleep.

This patient was the subject of many subsequent attacks, in every one of which the anger against S—— revived; until the current of thought changed, no longer running exclusively upon what related to her brother, but becoming capable of direction by *suggestions* of various kinds presented to her mind, either in conversation, or, more directly, through the several organs of sense. On one occasion, the attack having come on whilst she was alone, she managed to make her way down stairs, along a passage, and out into the garden by a back-door, although completely paraplegic,—a very curious instance of *sleep-walking*. So nearly did her condition, in some of these attacks, approach the waking state, that the case might then be almost regarded as one of *double consciousness*,—that very curious affection, of which the subject seems to lead two distinct lives, A and B, in neither remembering what takes place in the other, but each state being, as it were, continuous with itself.

The preceding case is well adapted to illustrate the general characters of the somnambulistic condition: we have now to notice some of those peculiar phenomena which are presented in individual cases. The first of these to which we shall advert, is the extraordinary exaltation of the sensibility to external impressions through one or more of the organs of sense; which would seem to result, in some instances, from the concentration of the attention upon that one class of impressions, but which, in other cases, is independent of any such state of attention.* We have ourselves been particularly struck with this, in the somnambulism induced by the "hypnotic" process of Mr. Braid, to which we shall presently refer. We have seen unequivocal proof that the sense of smell has been exalted to an acuteness at least equalling that of the most keen-nosed ruminant or carnivorous animal; that the sense of hearing has been rendered equally acute; and that the sense of touch has been exalted, especially in regard to temperature, to a degree that would be scarcely credible, were not the phenomena in perfect keeping with the exaltation of the other senses. We are not aware that the sense of sight has ever been thus acted on. In most somnambulists it is altogether suspended; and those who claim to possess the power of clairvoyance, reading words inclosed in opaque boxes, &c., do not refer their power of doing so to any unusual acuteness of their visual organs, but attribute it to the development of an entirely new faculty, for the operation of which any such optical instrument as the eye is altogether unnecessary. Among the senses most commonly exalted in somnambulism, is that "muscular sense" by which all our voluntary movements are guided; and this seems to be so much increased in acuteness, as quite to replace the visual sense, in the performance of many of those operations for which sight is ordinarily requisite. Thus we find that sleep-walkers make their way over the roofs of houses,

* The young lady whose case we have just detailed, exhibited, in a former attack of nervous disorder, a most extraordinary acuteness of the auditory sense, so that it was difficult to prevent her from hearing everything that passed in the house. Of a conversation held in an ordinary tone, in a room two stories below, she could hear every word as distinctly as if it had passed in her own chamber. Yet she did not suffer pain, as might have been expected, from the excessive loudness of ordinary sounds.

steadily traverse narrow planks, and even clamber precipices; and this with far less hesitation than they would do in the waking state. The fact seems to be, that they are utterly unconscious of the danger they are incurring; and that the whole attention being fixed without any distraction upon the indications of the muscular sense, the requisite movements are performed under its guidance with steadiness and certainty. So, again, it is well known that somnambulists will write with their usual degree of neatness and regularity, when prompted to do so either by their own train of thought, or by some suggestion from without; and this, when it is perfectly certain that they cannot see. We have ourselves witnessed this in hypnotic experiments on two individuals, and made quite sure that vision could not be affording any assistance, by holding a large book between the eyes and hand of the writer. Not only were the lines well written, and at the proper distances, but the *i*'s were dotted and the *t*'s crossed; and in one instance, the writer went back half a line to make a correction, crossing off a word, and writing another above it, with as much correctness as if he had been guided by vision. The guidance of the muscular sense in this case may be compared to that which we ourselves receive from it, when ascending or descending a pair of stairs, or traversing a passage, to which we have previously been accustomed, in the dark; we know when we have come to the end, without having counted our steps, or in any way observed our progress, simply by the information we receive through the muscular sense. To the suspension, complete or partial, of the activity of one or more of the organs of sense, which may occur spontaneously, or may be induced by calling off the attention from it, reference has already been made.

The next point to be noticed is the readiness with which the train of thought may be guided, during the state of somnambulism, by the principle of *suggestion.* This is more, perhaps, the case in *artificial* or *induced* than in *natural* somnambulism; for in the latter there is frequently, as already pointed out, some dominant idea or set of ideas, from which the attention of the somnambulist cannot easily be distracted. In the former, the mind is like a weathercock, without the least fixity or self-control, but liable to be turned in any direction by the impressions to which it is subjected. It is one of the most curious and important of Mr. Braid's discoveries, that the suggestions conveyed through the muscular sense are among the most potent of any in determining the current of thought. Let the face, body, or limbs be brought into the attitude expressive of any particular feeling, or into a condition at all corresponding with that in which they would be placed for the performance of any voluntary action, and the corresponding mental state is at once called up. Thus, if the hand be placed upon the vertex, the somnambulist will frequently, of his own accord, draw his body up to its fullest height, and throw his head slightly back; his countenance then assumes an expression of the most lofty pride, and his whole mind is obviously possessed by the feeling. Where the first action does not of itself call forth the rest, it is sufficient to straighten the legs and spine, and to throw the head somewhat back, to arouse the feeling and the corresponding expression to its full intensity. During the most complete domination of this emotion, let the head be bent forward, and the body and limbs gently flexed; and the most profound humility then takes its place. So, again, if the angles of the mouth be gently separated from one another, as in laughter, a hilarious disposition is immediately generated; and this may be immediately made to give place to moroseness, by drawing the eyebrows towards each other and downwards upon the nose, as in frowning. Not only have we witnessed all these effects repeatedly produced upon numerous "hypnotised" subjects, but we have been assured by a most intelligent friend who has paid special attention to the psychological part of this enquiry, that having subjected himself to Mr. Braid's manipulations, and been only partially thrown into the "hypnotic" state, he distinctly remembers everything that was done, and can retrace the uncontrollable effect upon his state of mind which was produced by this management of his muscular apparatus.

So, again, not merely emotional states but definite ideas are thus excitable. Thus, if the hand be raised above the head, and the fingers are flexed upon the palm, the idea of climbing, swinging, or pulling at a rope is called up; if, on the other hand, the fingers are flexed when the arm is hanging down at the side, the idea excited is that of lifting a weight; and if the same be done when the arm is advanced forwards in the position of striking a blow, the idea of fighting is at once aroused, and the somnambulist is very apt to put it into immediate execution. On one occasion on which we witnessed this result, a violent blow was struck, which chanced to alight upon a second somnambulist within reach; his combativeness being thereby excited, the two closed, and began to belabour one another with such energy, that they were with difficulty separated. Although their passions were at the moment so strongly excited, that even when separated they continued to utter furious denunciations against each other, yet a little discreet manipulation of their muscles soon calmed them, and put them into perfect good humour. The power of the operator, in regulating the state of mind of such somnambulists, is almost unlimited; and surpasses the credibility of those who do not discern the very simple principle on which it is exercised. The facility with which particular feelings or ideas may thus be excited, will of course be dependent in part on the previous character and habits of the somnambulist.

Again, a very uncommon degree of power

may be determined to particular muscles, as Mr. Braid has shown, either by a suggestion (so to speak) applied directly to themselves, or by the induction of such a mental state as shall be most fitted to call them into energetic operation. Thus the extensor muscles of a limb may be excited to contraction by gently rubbing or pressing the surface above them; and this contraction may not merely raise the limb, but may keep it fixed in a cataleptiform manner for a much longer time than any voluntary effort could accomplish. This contraction may be caused to give way at any moment, by gently wafting a current of air over the same surface, which seems to call off the attention from the muscles to the skin. In order to throw an extraordinary degree of power into a group of muscles by a mental process, all that is required is to suggest the action, and to assure the somnambulist that it can be accomplished with the greatest facility if he will only determine to do it. Thus, we have seen one of Mr. Braid's hypnotised subjects, a man remarkable for the poverty of his muscular development, lift a twenty-eight pound weight upon his little finger alone, and even swing it round his head, — upon being assured that it was as light as a feather. We have every reason to believe that the personal character of this individual placed him above the suspicion of deceit; and it is obvious that if he had *practised* such a feat (which very few, even of the strongest men, could accomplish without practice), the effect would have been visible in his muscular development. The same individual declared himself altogether unable to raise a handkerchief from the table, after many apparently strenuous efforts; having been assured that its weight was too great for him to move. Of course, there was not an equal proof of the absence of deception in this second case as in the first; but if the reality of the first be admitted, there need be no difficulty in the reception of the second, since both are manifestations of that mental condition which has been shown to be so characteristic of this state, — the possession of the mind by a dominant idea, which, when infused into it (as it were) by the principle of suggestion, directs the bodily movements, and is not corrected by the teachings of ordinary experience, or even by present sensations, if the mental assurance be strong enough to cause these to be disregarded.

Of the *causes* of somnambulism, no very definite account can be given. In some persons this state recurs frequently, or even habitually; in others occasionally. In the case formerly detailed, its access might generally be traced to some strong mental emotion. Those in whom it presents itself *spontaneously* are said to be *natural* somnambulists; but it may be *induced*, not merely in them, but in others who have manifested no predisposition to it, by certain *artificial* procedures. In many cases this may be effected through the mind alone, the simple *expectation* of the result being sufficient to bring it about. Thus the Abbé Faria was accustomed to induce somnambulism by placing his patient in an arm-chair, and then, after telling him to shut his eyes and collect himself, pronouncing in a strong voice and imperative tone the word "dormez," which generally produced on the individual an impression sufficiently strong to give a slight shock, and occasion warmth, transpiration, and sometimes somnambulism. — The following case is another illustration of the effect of this state of expectation, acting in concurrence with a fixed position. The subject of it was a lady who had previously shown great susceptibility to the "mesmeric" and "hypnotic" processes. "We now requested our patient to rest quietly at the fire-place, to think of just what she liked, and look where she pleased, except at ourselves, who retreated behind her chair, saying that a new mode was about to be tried, and that her turning round would disturb the process. We very composedly took up a volume which lay on the table, and amused ourselves with it for about five minutes; when, on raising our eyes, we could see, by the excited features of other members of a little party that were assembled, that the young lady was once more *magnetised*. We were informed by those who had attentively watched her during the progress of our little stratagem, that all had been, in every respect, just as before. The lady herself, before she was undeceived, expressed a distinct consciousness of having felt our unseen passes streaming down the neck."*

Perhaps the most effectual of all modes of inducing somnambulism is that discovered by Mr. Braid, and practised extensively by him under the designation of hypnotism.† The following is his description of his mode of inducing it, and of the phenomena attending its production. "Take any bright object (I generally use my lancet-case) between the thumb and fore and middle fingers of the left hand; hold it from about eight to fifteen inches from the eyes, at such position above the forehead as may be necessary to produce the greatest possible strain upon the eyes and eyelids, and enable the patient to maintain a steady fixed stare at the object. The patient must be made to understand that he is to keep the eyes steadily fixed on the object, and the mind riveted on the idea of that one object. It will be observed that, owing to the consensual adjustment of the eyes, the pupils will be at first contracted; they will shortly begin to dilate, and after they have done so to a considerable extent, and have assumed a wavy motion, if the fore and middle fingers of the right hand, extended and a little separated, are carried from the object towards the eyes, most probably the eyelids will close involuntarily, with a vibratory motion. . . . After ten or fifteen seconds have elapsed, by gently elevating the arms and legs, it will be found

* Brit. and For. Med. Rev., vol. xix. p. 477.

† Neurypnology, or the Rationale of Nervous Sleep, considered in relation with Animal Magnetism, &c., by James Braid, M. R. C. S. E., &c.

that the patient has a disposition to retain them in the situation in which they have been placed, if he is intensely affected. If this is not the case, in a soft tone of voice desire him to retain the limbs in the extended position, and thus the pulse will speedily become greatly accelerated, and the limbs, in process of time, will become quite rigid and involuntarily fixed. It will also be found that all the organs of special sense, excepting sight, including heat and cold, and muscular motion or resistance, and certain mental faculties, are at first prodigiously exalted ; such as happens with regard to the primary effects of opium, wine, and spirits. After a certain point, however, this exaltation of function is followed by a state of depression, far greater than the torpor of *natural* sleep. From the state of the most profound torpor of the organs of special sense, and tonic rigidity of the muscles, they may at this stage be *instantly* restored to the *opposite* condition of extreme mobility and exalted sensibility, by directing a current of air against the organ or organs we wish to excite to action, or the muscles we wish to render limber, and which had been in the cataleptiform state. By mere repose the senses will speedily merge into the original condition again." We have ourselves frequently witnessed the induction of somnambulism after this method ; and whilst fully admitting its potency, we are bound to say that the almost invariable success which it has in the hands of Mr. Braid himself, appears partly due to the mental condition of the patient, who is usually predisposed to the " hypnotic " state by the expectation of its certain production, and by the assurance of a man of determined will that it *cannot* be resisted. When the hypnotic state, however, has been induced a few times in the manner just described, the subject can usually send himself to sleep very readily by looking at his own finger, brought sufficiently near the eyes to occasion a sensible convergence of their axes ; or even by simply standing still, and fixing the eyes on a distant point. In all cases, the fixation of the eyes is the circumstance of most importance; although the withdrawal of other stimuli has a decided influence in favouring the production of the effect. The peculiar condition of the *muscular* sense, as felt through the ophthalmic branch of the fifth pair, seems to have a closer relation with the subsequent state than has the condition of the visual sense; for the same effect may be produced at night, or in blind persons, if the eyes can be kept in a fixed position, especially in one that produces a feeling of muscular tension. And it seems to be in facilitating this, that the sense of sight comes into play in the operation just described. How far the mode in which the somnambulism is produced has an influence upon its phenomena, it may not be very easy to determine. For an account of these peculiarities, we must refer to Mr. Braid's treatise already quoted ; but we may cite the following, as having ourselves repeatedly witnessed it and satisfied ourselves of its reality. " The remarkable fact that the whole senses may have been in a state of profound torpor, and the body in a state of rigidity, and yet by very gentle pressure over the eye-balls the patient shall be instantly roused to the waking condition, as regards all the senses and mobility of the head and neck, in short, to all parts supplied with nerves originating above the origin of the fifth pair, and those inosculating with them,—whilst they will not be affected by simple mechanical appliance to other organs of sense,—is a striking proof that there exists some remarkable connection between the state of the eyes, and condition of the brain and spinal cord, during the hypnotic state. Another remarkable proof to the same effect is this ; Supposing the same state of torpor of all the senses, and rigidity of the body and limbs, to exist, a puff of air or a gentle pressure against *one* eye will restore sight to *that* eye, and sense and mobility to *one half of the body*—the same side as the eye operated on ;—but will leave the other eye insensible, and the other half of the body rigid and torpid as before." *

We consider that the experimental researches of Mr. Braid throw more light than has been derived from any other source upon the phenomena of *Mesmerism*. That there is much of reality mixed up with much imposture in these phenomena, is a conclusion at which most candid persons have arrived who have given their attention to them ; and we have little doubt that a searching investigation, carried on under the guidance of his results, would lead to something like a correct discrimination between the two. The induction of mesmeric somnambulism appears to us to be fully explicable by the facts we have previously stated, as to the influence of the mental condition of the patient,—namely, the state of expectation, and the additional confidence derived from the mental impression produced by the operator,—and as to the effect of the fixation of vision. The ordinary phenomena of the mesmeric somnambulism itself are in most respects identical with those of hypnotism, except in this particular,—that there seems to be a peculiar relation between the somnambulist and the mesmeriser, which does not exist between the somnambulist and any other individual, excepting one who is *en rapport* with the mesmeriser. This relationship may perhaps be not unreasonably regarded as the result of a dominant idea, which possessed the mind at the moment of falling asleep, and which continued to influence it so long as the somnambulism lasts. We have examined into the history of many cases, in which it was affirmed that mesmeric sleep was induced without any consciousness on the part of the subject of it that any influence was being exercised; but we have never been able to satisfy ourselves that such was unequivocally the case. When the patient was *expecting* the performance,

* Op. cit. p. 64. *note.*

and was waiting in quiescence for its commencement, the expectation alone was sufficient to induce the sleep. When the patient had *no* such expectation, all attempts to produce the sleep, that have come to our knowledge, have completely failed. Hence we are strongly inclined to the belief that the relation between the mesmeriser and the somnambulist is one of a purely mental character, and not the result of any new physical power. With regard to what have been termed the "higher phenomena" of mesmerism, we believe that without regarding them as the result of intentional deception, most of them are capable of receiving a very simple explanation on the principles already laid down, — namely, that in the state of somnambulism the senses, or some of them, are often endowed with a wonderful acuteness, which causes the mind to be acted on by impressions that might be affirmed to be too faint to be perceived; and that these impressions will suggest trains of thought, and give rise to respondent actions, which are frequently of a kind that the will *could* not produce. As to the reality of the so-called *clairvoyance*, repeated personal examination has led us to a negative conclusion. The sources of fallacy arising from the causes we have mentioned, as also from the tendency on the part of the bystanders to afford assistance by asking "suggestive" or "leading questions," and from their disposition to interpret the least shadow of a resemblance into a complete coincidence, are such as greatly to diminish the wonder that a firm belief in the reality of these phenomena should be entertained by many persons of excellent judgment and great discrimination and acuteness as to all ordinary matters.

A state in most respects corresponding with natural somnambulism is frequently induced by the inhalation of ether, chloroform, and other anæsthetic agents. Instead of being completely comatose, the patient, though quite unconscious of pain, may be awake to external impressions received through some of his organs of sense, so as during an operation to obey the directions given him in order to facilitate its performance; and yet he shall be completely unaware of what has taken place when the effects of the anæsthetic agent have gone off. But even the sense of pain may not be extinguished, and the patient may scream and struggle even more violently than in the waking state; and yet the whole is subsequently forgotten, or is remembered only as a troubled dream. It was further to be noticed that, during the employment of ether, the state of the nervous system induced by it appeared to be much influenced by the previous degree of confidence entertained by the patient as to its results. The more potent action of the chloroform, however, has prevented this influence from being so apparent.

(*W. B. Carpenter.*)

SMELL. — The sense through which we take cognizance of odours.

Of the nature of odorous emanations nothing is certainly known. They are generally supposed to consist of material particles of extreme minuteness, detached from the odorous body, and dissolved or suspended in the air. This idea derives its chief support from the facts that most odorous substances are volatile, that is, their loss of weight, when exposed to the air, shows that their particles really diffuse themselves through it, — that most strongly odorous substances are extremely volatile—and that circumstances which increase the volatility of such substances also augment their odorous powers. These general statements, however, are not without their exceptions. Thus, in the first place, we do not find that many gaseous substances are truly *odorous;* the pungent, irritating qualities, by which many of them are distinguished, not being perceived through the sense of smell but through that of touch. Again, although it is true that a great number of volatile liquids are odorous, the strength of their scent bears no constant proportion to their respective volatility; and water, which is so constantly diffused through the air, has no odorous property. And with regard to solids, we find that although some of those which are most strongly odorous are also volatile (such as camphor), yet this is not by any means universally the case; for it has been proved by experiment that no diminution in weight can be ascertained to take place in musk or amber, although they have been freely exposed to the atmosphere for many years, and have imparted their perfume to an almost incalculable volume of air. These considerations have led some philosophers to suppose that odorous emanations are not *material*, but *dynamical:* — in other words, that the impressions made upon our olfactory organ do not result from the contact of diffused particles detached from the odorous body; but that they are effected by a change propagated through the atmosphere or other medium, in the same manner as sound is produced by undulations that originate in the sonorous body, and are transmitted onwards, through some material medium, to the organ of hearing. There are strong objections, however, to this hypothesis. In the first place, we find that odours are not perceived unless the air, gas, or liquid in contact with the olfactory surface is, or has been, in direct continuity with the odorous body; the interposition of any substance which prevents the actual passage of the odoriferous medium being sufficient to prevent the transmission of the odour. This is by no means the case in regard to sound, or to any other agent that is known to be dynamically propagated; for we find many substances which are capable of *conducting* these agents, that is, of transmitting their influence through unlimited spaces; and this may be accomplished in spite of any number of interruptions in their continuity, provided the chain of conducting substances be complete. Thus, sonorous vibrations may be transmitted from air to liquids, from liquids to solids, from air to solids, from solids to air, &c.; and many such changes usually take place, before the vibrations originating in a sonorous body are communicated to the sentient extremities of the auditory nerve. The same is the case with heat, light, electricity, and other agents whose transmission is believed to be dynamical: that it is *not* the case in regard to odorous emanations must be regarded, therefore, as a powerful argument against the idea of their dynamical nature. Another argument may be derived from the well-known fact, that odorous emanations require such a *time* for their propagation, as corresponds rather with the *diffusion* of the odoriferous medium itself, than with the mere *conduction* of vibrations. Thus, in a house in which free communication is established throughout by passages, staircases, &c., but in which the course of air is not very direct from one part to another, any strong odour set free in one spot will be *gradually* diffused through the whole house, the rapidity being governed by the circumstances which favour or obstruct the movement of air. On the other hand, the transmission of sonorous undulations, which merely throw the air into vibration, is not dependent upon its movement, and is, indeed, but little influenced by it. This argument is, perhaps, yet more cogent than the former, and may be regarded as conclusive against the dynamical theory of odours.

It is not difficult to explain many of the apparent inconsistencies which attend the material theory. The varieties of the olfactive power among human beings are quite sufficient to prove, that a substance which is strongly odorous to one individual may not produce any impression on the smell of another, whose scent for other substances may nevertheless be very acute. And there is strong reason to believe that there is a great diversity in this respect amongst different species of animals, some appearing entirely insensible to odours which strongly affect others. That *we* do not appreciate an odour, therefore, is no proof of its non-existence; and we have no right to say of any volatile or gaseous substances, that they are not odorous, but simply that they are not odorous *to us*. Again, the sense of smell, like the other senses, is rather *relative* than *positive*; that is to say, it rather estimates a *change* in the condition of the surrounding medium, than its actual permanent state. This is fully proved by the fact that persons who habitually dwell amongst odours of any one kind, become, in time, entirely insensible to them, although their olfactive sense may remain of its full acuteness in regard to any different scent. This being the case, we at once perceive that water, oxygen, nitrogen, and carbonic acid *could* not, in accordance with the general laws of sensation, possess any odour to animals whose organs of smell are constantly imbued with them. We shall presently find that the moisture of the olfactory membrane is a necessary condition of its functional power; and thus neither fishes, which have their olfactory surface constantly bathed in water, nor air-breathing animals, whose pituitary membrane is lubricated with it, could take cognisance of any odorous properties which it might really possess. In like manner, the nasal cavities of animals being continually filled with a mixture of oxygen, hydrogen, and carbonic acid, these gases cannot excite the olfactive sense; whilst on the other hand, we can easily imagine that if animals were adapted to breathe hydrogen or its strongly odorous compounds, they would be insensible to the latter, whilst they might distinguish oxygen, nitrogen, or carbonic acid by their respective odours, just as readily as *we* distinguish phosphuretted, sulphuretted, or carburetted hydrogen.

Although it is through the atmosphere that odorous emanations are most readily conveyed, yet there can be no reasonable doubt that they may be transmitted through water also. Thus we find fishes provided with a complex organ of smell, which seems to be of considerable importance in directing them towards their prey. This may be inferred, not merely from the fact that the olfactive ganglia and nerves are of large size relatively to the rest of the encephalon, but also from the circumstance, well known to fishermen, that many fish are particularly attracted by odorous bait. Some anglers are even in the habit of scenting their bait with essential oils, in order to render it more alluring.

The general structure of the *organ of smell* in man has already been described (NOSE); but some particulars recently ascertained by Messrs. Todd and Bowman respecting the minute anatomy of the pituitary membrane, and the structure and distribution of the olfactory nerve, are too important to be passed by. That the true sense of smell is specially, if not exclusively, the endowment of the upper portion of the organ, has been inferred by anatomists from the limited distribution of the olfactory nerve, and by physiologists from the fact that odours are only perceived strongly when the odoriferous air is drawn into the upper part of the cavity. The lower part of the nasal cavity is properly to be regarded as the orifice of the respiratory passages: it is extremely sensitive to *irritants*, but it does not participate in the discrimination of *odours* properly so called; and its mucous membrane is covered with a ciliated columnar epithelium. On the other hand, the limits of the olfactive region "are distinctly marked by a more or less rich sienna-brown tint of the epithelium, and by a remarkable increase in the thickness of this structure compared with the ciliated region below; so much so, that it forms an opaque soft pulp upon the surface of the membrane, very different from the delicate, very transparent film of the sinuses and lower spongy bones. The epithelium, indeed, here quite alters its character, being no longer ciliated, but composed of an aggregation of superposed nucleated particles, of pretty uniform appearance throughout; except that, in many instances, a layer of those lying deepest, or almost deepest, is of a darker colour than the rest, from the brown pigment contained in the cells. These epithelial particles, then, are not ciliated; and they form a thick, soft, and pulpy stratum, resting on the basement membrane. The deepest layer often adheres after the others are washed away." The vessels of the olfactive membrane in the fœtus present a regular series of papillary loops; but these cannot be seen in the adult. "The olfactory filaments form a considerable part of the entire thickness of the membrane, and differ widely from the ordinary cerebral nerves in structure. They contain no white substance of Schwann, are not divisible into elementary fibrillæ, are nucleated and finely granular in texture, and are invested with a sheath of homogenous membrane." These nerves thus rather correspond with the gelatinous fibres, than with the ordinary tubular fibres of the trunks and branches of true nerves; and they are regarded by the authors as direct continuations of the vesicular matter of the olfactory bulb or ganglion. "Although these nucleated olfactory filaments lie in great abundance under the mucous membrane of the olfactory region, we have been quite foiled in our attempts to trace their ultimate distribution in the membrane, and the difficulty is attributable to their want of the characteristic white substance. Their elongated nuclei render the larger branches unmistakeable; but if these become resolved at last into fibrous elements, the nuclei cease to be distinct from those of the numerous nucleated tissues which they traverse." "We are averse from speculating prematurely on the meaning of anatomical facts; but as some hypothesis will intrude itself, we would venture to hint that the amalgamation of the elements of the peripheral part of the nervous apparatus in the larger branches, and probably in the most remote distribution, as well as the nucleated character indicative of an essential continuity of tissue with the vesicular matter of the lobe, are in accordance with the oneness of the sensation resulting from simultaneous impressions on different parts of this organ of sense, and seem to show that it would be most correct to speak of the first pair of nerves as a portion of the nervous centre put forward beyond the cranium, in order that it may there receive, as at first hand, the impressions of which the mind is to become cognisant."* It has also been remarked by the same excellent observers †, that on the septum narium and spongy bones bounding the direct passage from the nostrils to the throat, the lining membrane is rendered thick and spongy by the presence of ample and capacious submucous plexus of both arteries and veins, of which the latter are by far the larger and more tortuous. And they surmise, with much probability, that the chief use of these may be to impart warmth to the air, before it enters the proper olfactive portion of the cavity; as well as to afford a copious supply of moisture, which may be exhaled by the abundant glandulæ seated in the membrane. "The remarkable complexity of the lower turbinated bones in animals with active scent, without any ascertained distribution of the olfactory nerves upon them, has given countenance to the supposition that the fifth nerve may possess some olfactory endowment, and seems not to have been explained by those who rejected that idea. If considered as accessory to the perfection of the sense in the way above alluded to, this striking arrangement will be found consistent with the view which thus limits the power of smell to the first pair of nerves."*

The olfactive organ, in other air-breathing Vertebrata, corresponds with that of man in all the essential particulars of its structure; being a cavity opening anteriorly upon the face by the external or anterior nares, and posteriorly into the upper part of the pharynx by the internal or posterior nares. It may thus be considered as the entrance of the respiratory passages, which is dilated for the extension of the olfactive membrane; or, perhaps, it would be more correct to speak of it as a diverticulum from the commencement of the respiratory tube, since, as we have seen, the proper olfactive organ does not extend into that portion of the cavity which is placed in a direct line between the anterior and posterior nares. The development of the olfactive organ, as measured by the size of the olfactory ganglia and nerves, and by the extent of the surface over which these are distributed, varies greatly in different tribes; and details must be sought on this subject under the respective names of the classes and orders of vertebrata. The chief departure from the ordinary type is observable in the case of the Cetacea, in which the nasal cavity is almost entirely devoted to the purposes of respiration, and to the ejection of the water taken in by the mouth with the food. To animals which seek their prey in the water, an organ of smell, adapted to take cognisance of odorous emanations contained in the inspired air, would obviously be entirely useless; and it is probable that whatever olfactive power they possess is called into exercise by the passage of the water that is spouted through the nostril. The ordinary statement that the Cetacea are entirely destitute of olfactive ganglia and nerves, and that they must therefore be entirely devoid of the sense of smell, is true only of the *Delphinidæ*, or that division of the order which includes the dolphins and porpoises; for the *Balænidæ*, or proper whales, do possess olfactive nerves, although these are comparatively of small size; and in the *Manatidæ*, or herbivorous whales, which properly belong rather to the Pachydermata

* Physiological Anatomy and Physiology of Man, vol. ii. pp. 5—11.

† *Op. cit.* p. 3.

* Op. cit. p. 12.

than to the Cetacea, the olfactive apparatus is formed after the usual type.

In Fishes, however, the plan is altogether changed, the organ of smell being no longer connected with the respiratory passages, but disposed in a cavity peculiar to itself, which opens externally by anterior nares, but has no internal communication by means of posterior orifices.

No distinct organ of smell has yet been discovered in the Dibranchiate Cephalopoda; but in the *Nautilus*, a peculiar laminated organ, strongly resembling the olfactive organ of fish, has been considered by Prof. Owen as an olfactory apparatus. The inferior Mollusca would seem to be altogether destitute of special organs of smell; but as there is much reason to believe that some of them, especially the terrestrial Gasteropods, are guided to their food by its scent, it would not seem improbable that some part of the soft spongy glandular mantle, in which the entire body is enveloped, may be adapted to take cognizance of odorous emanations; or that in the air-breathing species, the entrance to the respiratory sac should be endowed with a low degree of this power.

There is ample reason to infer, from observations of the actions of Insects, that these animals possess the olfactive power in no inconsiderable degree; and yet no special organ for this sense has hitherto been satisfactorily made out. That many insects are guided to their food, to the proper nidus for their eggs, and to the opposite sex of their own species, and are even informed of the proximity of their natural enemies, by odorous emanations, can scarcely be doubted by any one who watches their habits, and who experiments upon their actions under a variety of circumstances. Thus, the flesh-fly will be attracted by the odour of decomposing meat, when this is completely hid from its sight; and will deposit its eggs on the envelope with which it may be covered. On the other hand, the same insect is deceived by the odour of the *Stapelia*, or carrion-flower, and is led to deposit its eggs in its petals. Again, many male insects will show that they are aware of the proximity of their females, when the latter are shut up in boxes, so as to he hid from their sight, and utter no sound. And in like manner, when a predaceous insect or spider is shut up in a box that gives a sufficiently free passage to air, the small insects on which it preys will manifest their alarm at its proximity, and will endeavour to make their escape. Some entomologists have supposed the seat of the olfactory sense of insects to be in their antennæ, others in the palpi, and others in the entrances to the air-tubes. No evidence can be adduced in favour of either of these suppositions that is satisfactory enough to prove it, and we have little other guide at present than *à priori* probability. In regard to the last of the three suppositions, however, it may be remarked that all analogy opposes the idea that the true olfactory apparatus should be thus scattered amongst the several segments of the body; and the experiments which appear to favour it really lead to no other conclusion than this, that acrid or irritating vapours, taken in through the breathing-pores, may excite reflex movements which seem destined to expel them, or to withdraw the body from them. Such movements resemble those of coughing and sneezing in man, which are excited through the nerves of common sensation, and not through the first pair; and they do not in the least indicate, therefore, that the sense of smell is in any way connected with the respiratory apparatus of insects, myriapods, &c. The use which many insects may be seen to make of their palpi, in taking cognizance of their food without actually touching it, suggests the idea that they are the true olfactive organs; and this idea is borne out by the fact, that these organs terminate, in the living state of many insects, in soft bulbous expansions, which shrivel up and become horny in the dead specimen, thereby obscuring their real character. On the other hand, many insects are furnished with soft membranous appendages at the base of their antennæ, which seem equally adapted to perform this function. And it is asserted by Dugès *, that insects whose antennæ had been cut off did not manifest the same cognizance of the neighbourhood of odorous substances, as did others of their kind whose antennæ had been left entire. It would seem not a very improbable supposition that, as the antennæ and palpi are organs of a similar class, the sense of smell may not be localised in one or other of them constantly; but that it may be assigned to one or the other, according to the modifications they may respectively require for the performance of their other offices. The same doubt exists in regard to the olfactive organ of the Crustacea. The manner in which crabs and lobsters are attracted by odorous bait placed in closed traps, makes it almost certain that they must possess some sense of smell; and the most probable locality of the organ would seem to be a cavity discovered by Rosenthal at the base of the first pair of antennæ.

As to the existence or absence of the sense of smell in the lower Invertebrata, nothing can be definitely stated.

Nerve of smell. — That the *first pair* of cranial nerves is the true *olfactive*, and that through it alone are the proper odorous emanations perceived, would seem a legitimate inference from the fact, that its development in vertebrated animals is constantly proportionate, *cæteris paribus*, to the acuteness of the sense; and that it is chiefly distributed to that part of the nasal cavity, which is most distinguished by the possession of this endowment. This inference is fully borne out by the facts supplied by experiment and pathological observation. The division of the olfactory nerves in animals evidently produces a complete destruction of the power of perceiving odours; although they are still affected

* Physiologie Comparée, tom. i. pp. 160, 161.

by irritating vapours. They do not immediately perceive these vapours, however, but seem indifferent to them at first, and then suddenly and vehemently avoid them as soon as the Schneiderian membrane becomes irritated. It was maintained by Magendie that the fifth pair in some way furnishes conditions requisite for the enjoyment of the sense of smell; this sense being destroyed, according to his assertion, by section of its trunk. His experiments, however, were made with irritating vapours which excite sternutation; and he inferred the loss of the sense of smell from the absence of the automatic movements which these vapours normally excite. This inference was altogether unjustifiable; since the experiments in question afford no proof that the power of perceiving *odours*, with which the excitement of automatic movements does not appear to be in any way connected, is destroyed by section of the fifth pair. A diminution in the acuteness of the true sense of smell, however, appears to be a usual result of paralysis of the fifth pair; but this is readily accounted for by the diminution of the normal secretion of the pituitary membrane, by which its surface is deprived of the moisture that is necessary for the exercise of its sensory powers. The difference in the endowments of the first and fifth pairs of nerves, and the speciality of the former, are further marked by the result of mechanical irritation of their trunks and branches. Such irritation of the first pair excites no muscular movement, either direct or reflex, and it produces no indication of pain. On the other hand, irritation of the nasal branches of the fifth pair is obviously attended with violent pain, and excites various automatic muscular movements. Lastly, it has been found that in cases of deficiency or loss of the sense of smell, some abnormal condition of the olfactive nerves or ganglia has existed; and the same kind of change has been discovered in cases in which *subjective* sensations (*i. e.* sensations not originating in external objects) had existed during life.

Conditions of the exercise of the sense.—The first condition requisite for the exercise of the sense of smell, is the contact of the odoriferous medium with the olfactive surface. This may be favoured or prevented by a variety of circumstances. Thus, odours are more rapidly transmitted by air in motion than by air at rest; but they only proceed in the direction of the movement: and hence animals possessed of the keenest scent, which would be alarmed by the presence of a human or other foe a mile off on the windward side, may be approached within a short distance on the leeward, when a fresh breeze is stirring. The odoriferous medium must not only be brought *to* the nose, but it must be introduced *within* the olfactive cavity. This is usually accomplished by the ordinary movement of inspiration, which draws a current of air through the nose; but as the current chiefly passes through the lower part of the nasal cavity, to which the olfactive nerve is very sparingly or not at all distributed, the full use of the sense of smell is not thus gained. It is only by making a series of short and *quick* inspirations,—the effect of which seems to be, to empty the *whole* nasal cavity of the air it previously contained, and thus to cause the newly-inspired air to pass forcibly into its upper part, instead of merely streaming through the passage between the anterior and posterior nares,—that we employ our olfactive powers to the best advantage. This movement, combined with the direction of the nostrils towards the source of the odour, and with the dilatation of their orifices by the muscles adapted for that purpose, constitutes the *active* exercise of the sense, which may be termed *scenting*. This bears the same relation to ordinary smelling, as feeling bears to touch, listening to hearing, or looking to seeing. The effect of the sensory impression on the mind is further heightened by the attention which is bestowed upon it; and it does not seem improbable that the sensation itself is rendered more acute by an increased determination of blood to the olfactive surface when it is being thus actively employed. On the other hand, the use of this sense may be prevented, not merely by the closure of the nares, anterior and posterior, so as completely to exclude the odoriferous medium, but also by simply refraining from drawing air into the nasal cavity. If we breathe through the mouth only, closing the posterior nares by means of the velum palati, we may avoid being affected by odours even of the strongest and most disagreeable kind; for the nasal cavity being already filled with air, there is no room for the entrance of the odoriferous atmosphere from without; and it may thus be long before the odorous particles come into contact with the olfactive surface.

It is, of course, an essential condition of the exercise of this sense, that the whole nervous apparatus, which forms the essential part of its organ, should be in a state of integrity; and that a free circulation of blood shall take place through the olfactive portion of the pituitary membrane. But, in addition, it is requisite that the epithelial and mucous covering of the membrane be in a normal state. If the surface be too dry, the odorous particles cannot undergo that solution in the fluid in contact with the sentient extremities of the nerves, which seems necessary for the production of an impression on them. On the other hand, when the secretion is too abundant, it interferes with its contact in the opposite manner. And thus it happens that the sense of smell is blunted, both in the primary and secondary stages of an ordinary cold, by the disorder of the secreting surface, independently of the effect which the disturbance of the circulation may have upon the functional power of the olfactive nerve.

Purposes of the sense.—When we take a comprehensive survey of the animal kingdom, we at once perceive that the most *general*, and therefore the most *essential* purpose of the sense of smell, is to make known the presence of food, to indicate its direction and thus to guide the animal towards it, and to aid in the discrimination of its qualities. We *always* find the olfactive organ placed in the neighbourhood of the mouth; its connection with the respiratory apparatus is by no means so constant. In air-breathing vertebrata, whose olfactive cavity opens into the pharynx, the sense of smell largely participates in that of taste (see TASTE), being the means by which we take cognisance of the *flavours* of sapid bodies introduced into the mouth. Of the importance of this sense in directing animals to their food, it is needless to multiply instances; but we may remark that, from observation of the actions of the human infant, we are well convinced that it is rendered cognisant by smell of the neighbourhood of its nurse, long before it recognises her by sight, and that this sense is its guide in seeking the source of its nutriment. How purely instinctive this action is, — that is, how completely independent of all experience, and entirely dependent upon the provocative sensation, — is well shown by the experiment of Galen, who placed a kid, just dropped, near three vessels, one filled with milk, another with honey, and another with wine; after smelling at all three, it presently began to drink the milk. It would seem to be by the information conveyed through their smell, that bees are induced to fly to pastures at a great distance from their hive; and it would not seem improbable that the sense of *direction*, which is so remarkably displayed by many animals, is the result of the acuteness of their olfactive power. Whilst the chief use of smell to the carnivorous tribes is to guide them to their prey, the herbivorous races, whose food is constantly within their reach, are warned by its means of the neighbourhood of their enemies. The sense of smell is subservient to defence in another way; being the means by which the fœtid scents, emitted by many animals under the influence of alarm, deter their enemies from further pursuit. In nearly all animals, the sexual secretions are more or less odorous; and these would seem to be intended, not merely to contribute to make the sexes aware of each other's proximity, through the sense of smell, but also, in many instances, to serve as a provocative to sexual desire. The odours which are attractive to animals are usually related either to their food or their sexual instinct; but there are cases in which animals seem to delight in odours which have no such relation: thus, cats seem to revel, as it were, in the odour of Nepeta (catmint) or Valerian.

In the air-breathing vertebrata, the sense of smell is, as it were, the sentinel of the respiratory organs, having for its office to take cognisance of the aeriform fluids which enter them, and to give warning of such as are injurious. The contact of *irritating* matters, however, is perceived (as already stated) through the general sense of feeling, not the special sense of smelling; and it is through the fifth pair that the act of sneezing is excited, the purpose of which is to expel such particles from the nasal cavity. The distinction is well seen in some air-breathing invertebrata, whose organ of smell is seated in the head, whilst the impression of irritants on the respiratory surface, exciting reflex movements for the purpose of avoiding or expelling them, is made through the stigmata. Thus M. Dugès relates* that if the stigmata on one side of a decapitated Scolopendra be exposed to an irritating vapour, the body will be immediately flexed in the opposite direction; and that if the stigmata on the opposite side be then similarly irritated, a contrary movement will occur; whilst by exposing the anterior stigmata on one side, and the posterior on the other, to the same irritation, the body will be bent into the form of the letter S.

In man, the sense of smell is not ordinarily so acute as it is in many of the lower animals; yet it is very possible that it may be capable of taking cognisance of a greater *variety* of odours. In the selection of his food, it is to him by no means the infallible guide that it seems to be in many other races; for it not only gives no warning, in many instances, of what is noxious, but renders certain poisonous substances (as, for instance, those charged with prussic acid or the essential oil of almonds) positively attractive. So, again, in regard to the respiratory organs, whilst it gives warning of the presence of certain gases and emanations which are injurious, it takes no cognisance of many others which are not less hurtful. In the ordinary conditions of civilised life, man is not dependent upon his sense of smell for many of the ends which it answers in other animals; hence this sense is altogether subordinate to others, and the want of it is not usually attended with any great inconvenience. But the case is far different among savage tribes, to whom it is as important as it is to other animals in a state of nature, and in whom it seems to acquire, by the constant habit of attention to its indications, a similar acuteness. Thus, it is stated by Humboldt that the Peruvian Indian, in the middle of the night, is informed of the proximity of another individual by his smell, and can distinguish by his smell whether the stranger be an European, an American Indian, or a Negro. It has even been asserted that some other savage tribes of mankind are enabled to follow a track by the scent of the footsteps, like the bloodhound. The sense of smell, moreover, usually acquires great acuteness, when, from deficiency of the other senses, its indications become the chief or only means of recognising bodies not in immediate contact with the individual. Thus, in the well-known case of James Mitchell, who was deaf, blind, and dumb from his birth, it was the principal means by which he distinguished persons, and enabled him at once to perceive the entrance of a stranger. Mr. Wardrop gives the following curious account of the mode in which he exercised this sense, and of

* Op. cit. tom. i. p. 162.

the information which he derived from it:—"There were some people whom he never permitted to approach him, whilst others at once excited his interest and attention. The opinions which he formed of individuals, and the means he employed to study their character, were extremely interesting. In doing this, he appeared to be chiefly influenced by the impressions communicated to him by his sense of smell. When a stranger approached him, he eagerly began to touch some part of his body, commonly taking hold of the arm, which he held near his nose, and after two or three strong inspirations through the nostrils, he appeared to form a decided opinion regarding him. If this was favourable, he showed a disposition to become more intimate, examined more minutely his dress, and expressed by his countenance more or less satisfaction; but if it happened to be unfavourable, he suddenly went off to a distance with expressions of carelessness or disgust. When he was first brought to my house to have his eyes examined, he both touched and smelled several parts of my body; and the following day, whenever he found me near him, he grasped my arm, then smelled it, and immediately recognised me, which he signified to his father by touching his eyelids with the fingers of both hands, and imitating the examination of his eyes which I had formerly made." We learn from the same account, that in selecting his food, he was always guided by his sense of smell, for he never took anything into his mouth without previously smelling it carefully. He always recognised his own clothes by their smell, and refused to wear those which belonged to others.

Sometimes the peculiar acuteness of this sense is restricted to a particular odour or class of odours, these usually proceeding from objects for which there is either a special fondness or a particular aversion. Thus, a gentleman blind from birth, who had an unaccountable antipathy to cats, so that he could never endure the presence of one in his apartment, one day, when in company, suddenly leaped up and exclaimed that a cat was in the room, begging his friends to remove it. It was in vain that, after careful inspection, they assured him that he was under an illusion. He persisted in his assertion, and his agitation continued; and on the door of a small closet being opened, it was found that a cat had been accidentally shut up in it.

With such unequivocal proofs of the acuteness of the sense of smell which may exist in the human subject, the statements made respecting the extraordinary exaltation of the faculty in various forms of somnambulism become less incredible; and the author is fully satisfied, from his own observations upon individuals *hypnotised* by Mr. Braid (see SLEEP), that this exaltation may certainly take place in regard to the sense of smell. In one instance, a glove being placed in the hand of the hypnotised subject, he found out the owner of it without difficulty, from amongst more than sixty persons, scenting at each of them, one after another, until he came to the right individual. And in another case, the owner of a ring was in like manner unhesitatingly found out from amongst a company of twelve.

The information conveyed by the sense of smell is restricted to the *quality* and *intensity* of the odour, and to some general notion of its *direction*. This last, indeed, is rather derived from a comparison of its relative intensity when the face is turned towards different sides, than from any more direct information as to locality furnished by the organ itself. The absence of any consciousness of the part of the olfactory surface specially affected by the impression,—so that, unless the experiment be made, we know not that we are constantly exerting the sense on both sides, the double sensation being perceived as a single one,—is attributed by Messrs. Todd and Bowman*, with much probability, to the peculiar plexiform arrangement of the fibres of the olfactive nerve, and to the want of the isolation usually effected between the fibres by the white substance of Schwann.

Various classifications of odours, founded upon the impressions which they make upon the sense of smell, have been proposed; but they are all liable to the objection, that there seems to be more of individual diversity in regard to the character of olfactory impressions, than with respect to those of any other kind. Many odours, by some persons thought intolerable, are very agreeable to others; thus, assafœtida is known amongst some by the name of "devil's dung," whilst by others it is spoken of as "food for the gods." It was commonly employed by the ancients as a condiment; but the individuals who thus relish it in our own country certainly constitute the exceptions to the mass. So, again, the *fumet* of game, so highly valued by the epicure, is disagreeable to most persons who have not been trained to appreciate it. On the other hand, the aroma of certain flowers, which is peculiarly agreeable to most persons, is by no means so, or perhaps the reverse, to others. Thus, Müller remarks that the smell of mignonette is to him only herb-like; whilst the flower of *Iris Persica* has been pronounced to be of pleasant odour by forty-one out of fifty-four persons, by four to have little scent, by eight to be without all odour, and by one to be ill-scented.†

It more frequently happens, in regard to odours and savours, than with respect to other sensory impressions, that habit renders that agreeable, and even strongly relished, which was at first highly repugnant.

(*W. B. Carpenter.*)

SOFTENING and INDURATION (*Ramollissement et Induration*,—*Endurcissement*, Fr., *die Erweichung und Härtung*, Germ.) are terms used to express a pathological or physiological diminution and increase, of the consistence of the body or its parts.

* Op. cit., p. 12.

† Arnold's Physiology, vol ii. p. 561.

Softening and induration in a physiological sense, refer to those changes which occur in the density of tissues and organs during their development, growth, and decay ; whilst, in a pathological sense, they refer to alterations in the normal consistence, with or without actual molecular change.

In order to be able to distinguish morbid alterations of cohesion, from those which occur in the natural course of things, it is necessary to be well acquainted with the power exercised by age, sex, and idiosyncrasy, in modifying the density of the tissues.

Softening and induration are but relative terms, the standard of consistence is constantly varying, both as regards the whole body, or as regards organs and tissues. In the fœtal state all the tissues are soft, and contain large quantities of fluid ; as development proceeds, so do the parts gradually become hard, not all equally so, for certain tissues remain permanently soft in comparison to others, which rapidly increase in density. After birth, the hardening processes still continue, and it is not until the age of puberty is passed, that all the tissues have attained their highest stage of development. But the process of natural hardening is interfered with, or retarded, by peculiar idiosyncrasy and by the influence of sex and occupation; the general firmness of the tissue of an athlete is greater than that of those, who, although in perfect health, happen to lead inactive and sedentary lives ; it is greater as a general rule in the male than in the female sex, and in the sanguineous than in the lymphatic temperament.

As old age comes on, changes in the consistence of the tissues occur, which are produced by the natural decay to which all organized matter is subject ; thus the cellular tissue, the serous and mucous membranes, the muscles and tendons, bone, the brain and nervous system, and particularly the uterus and ovaries, sometimes acquire a degree of hardness, equal to that which is known to be produced by certain diseases.

Finally, after death the whole organism is affected by forces, which had little or no influence upon it during life ; the tissues are subjected to the macerating influence of their fluids, which may also act chemically upon them. In the natural course of things, softening and putrefaction, and disorganization of the ultimate atoms of our body occur, before they are fitted to be assimilated into other organized structures ; this decay increases as time progresses, and is enhanced by a high state of temperature and exposure to the air. After death, hypostatic congestion of the cellular tissue simulates the appearance that this structure frequently presents, when affected with inflammatory softening ; and the macerating effects of the fluids, which had no such influence during life, are seen in the brain and spinal cord ; whilst the alimentary mucous membrane suffers softening and disintegration from the peculiarities of the fluid usually secreted by it. By recognising then the normal alterations of cohesion, and those arising from post mortem causes, the attributes of morbid softenings will become perfectly apparent.

Softening and induration are said to exist without any structural change ; such is not generally the case, indeed it is exceptional, and were such a state only to be properly termed softening and induration, many of the most important and interesting pathological facts would be unaccounted for. Softening and induration are produced by a variety of causes, and frequently co-exist in the same organ, or one may supervene on, or cause, the other.

Both softening and induration may be produced by inflammation leading, on the one hand, to effusion of serum and pus, and on the other to the deposition and subsequent contraction and hardening of coagulable lymph ; the one appears to be the result of acute, and the other of subacute, inflammatory action. Active sanguineous congestion produces in some organs the sensation of diminished consistence, whilst in others, especially in those surrounded by a dense fibrous tissue as the testicle, hardening results. In softening, the effused product of inflammation, appears not only to break down the structure by infiltration, but also by its pressure to impede the usual nutrition of the part.

The softening of an organ, induced by inflammatory action, is frequently confined to one of the component tissues, especially to the cellular tissue ; the readiness with which the serous envelope may be stripped from off a parenchymatous organ, depends more upon the subserous cellular tissue, than upon the other structures ; and, in like manner, the softness of a whole organ is often assignable, rather to the deficient tenacity of the membrane which unites its lobules, than of the proper tissue.

Softening may be produced by causes totally differing from those produced by inflammation ; it may depend upon a deficiency or perverted state of the blood, and an anæmic state of the general system. For instance, in white softening of the brain, the arteries, which ought to have sufficiently nourished the affected parts, fail to do so on account of their being blocked up, more or less, by abnormal deposits. In certain softened states of the spleen, the blood contained in its parenchyma loses its consistence, and becomes more fluid than natural, from a perverted state of its constitution ; and the flabby muscles and general loss of tone of anæmic subjects are notorious.

In scrofula, the perverted state of the general nutrition produces softening of peculiar tissues, for instance, of the bones ; and in the cancerous cachexia like effects occur.

Long continued functional inactivity, for instance of the muscles of an extremity stricken with paralysis, tends to produce softening ; and pressure, in certain instances so interferes with the nutrition of a part as to diminish its cohesion. Fatty deposit in the ultimate cells of tissues and organs, renders them soft and flabby; as will also infiltrations of certain morbid adventitious products. The compound granule cells found in acute softening of the brain, and mixed with pus in other situations, are described in the article on ADVENTITIOUS PRODUCTS. Softening may be accompanied by atrophy, or by hypertrophy, which is generally produced by simple congestion; or no alteration of bulk may occur. Three degrees of softening are recognised:—in the first, the softened tissue is still solid, but it breaks down and tears and can be perforated with ease; in the second, all solidity is gone, nothing but a pultaceous semi-fluid mass is found; and, in the third degree, the tissue is broken down and diffluent.

Softened parts may retain their natural colour, or may be paler, or may have an increase of colour. Softening, without any change of tint, occurs in mucous and serous membranes, in the brain, heart, liver, and uterus. All post mortem softenings are of this kind, except where the colouring matter of the blood has tinted the effused fluids.

In certain softenings of the brain the affected parts are much paler than usual, being of a dead white colour; there is a diminution in the quantity of blood usually present in the diseased parts; a like decrease of colour is found in other softenings.

Generally, however, softening is accompanied by reddening, or by an increased colour; the tints may vary from a bright vermilion to a brownish red, and may be seen as grey, almost black, and, occasionally, are yellow. These varieties of colour depend upon the amount of blood usually existing in the softened tissue, and upon the degree of congestion. The redness of softened tissues is occasionally partial, and merges into lighter tints as the tissue becomes harder. Partial effusions of blood, or highly injected vessels, are commonly found in red softenings.

Induration, generally speaking, is to be regarded as a symptom of previous or coexisting diseased states; its physical condition varies much in its nature, in the same or in different tissues, as proved by microscopical, mechanical, and chemical analysis; and both observation and experiment tend to prove, that it is produced by causes of a very opposite kind.

Changes in the amount of fluid destined for the nutrition of a part, frequently give rise to induration; an increased quantity of blood and a consequent increased deposit of solid structure, produce simple induration of many organs, which are liable to variations in the quantity of blood they may contain, for instance, the brain and spinal marrow, the cellular and muscular tissues; also of denser structures, as bone, in which the induration is occasionally extreme, and in fibrous tissues; they produce also hardening of the lymphatic glands and of the salivary glands. The brain has been found to be increased to twice its natural density and consistence. Muscular, fibrous, and cellular tissues, become so hard, as to give out a grating sound when cut; and the walls of some hollow organs, naturally soft and flaccid, acquire such a degree of firmness, that they preserve, when empty, a globular or cylindrical form, and spring up with considerable force after sudden pressure; and parts of bone acquire that degree of hardness, which has been termed eburneoid induration. An increased quantity of the usual fluids of nutrition frequently gives rise to induration, differing from that just described, in not being attended by deposition of solids. The accumulation of blood in the vessels of the lungs and spleen, the result of congestion, produces, sometimes, a great degree of hardness and density of these organs. Diminution of the quantity of the same fluid, especially when there is also a compressing force, is also followed by an increase of consistence, and, generally, by a decrease in bulk of certain organs; in pleurisy, for instance, dense false membranes, by their pressure, compress the lung into a small space, and its tissue becomes indurated from simple approximation; for, on the removal of the compressing agents, the lung can be inflated.

The inordinate increase and accumulation of the secretion of certain organs, as the mamma, testis, gall bladder, and kidney, produce a degree of hardness, sometimes equal to that of dense tumors, arising from the incompressibility of the fluids themselves, and the state of condensation of the walls of the organs in which they are accumulated.

Effusions of serum and blood into the tissues from mechanical causes produce great distension and induration; such is the case in the œdema of the cellular tissue of the extremities in dropsy; effusion of serum into the intermuscular cellular tissue produces hardening. Pulmonary apoplexy and ecchymosis in various organs, from a mechanical impediment to the return of blood to the heart, have a like effect.

But inflammation of a sub-acute form is the great cause of induration, from the effusion of serum and coagulable lymph; the former of which is absorbed, and the latter becomes "induration matter," whose properties are described under the head of ADVENTITIOUS PRODUCTS; this last product produces induration on account of its being actually denser than the tissues into which it is effused, and, also, by its compressing power, for it has the peculiarity of contracting and becoming hard after its deposition. Certain morbid states of the blood, occasionally produce indurations of certain organs.

The changes of form, with which induration may be connected, are numerous; none may, however, occur; the bulk also of indurated structures varies; it may remain unchanged, but, generally, it is increased, and more rarely, decreased.

The colour of indurated parts, is generally different from the normal tint; sometimes, owing to diminished vascularity, and to the presence of induration matter, it may be pale; at others, owing to increased vascularity, and the state of the fluids of the tissue, and the presence of effused or infiltrated matters, it may be bright or dark red, grey, yellow, and sometimes almost black.

Induration presents several degrees of resistance to pressure or to the knife ; much depends on the ordinary cohesion of the affected organ. Generally speaking, the first degree is characterised by a slight increase in the resistance to pressure; the second finds the tissue denser, cutting with a cracking noise; and the third comprehends increased cohesion, amounting to a cartilaginous or bony hardness.

Softening of the brain may be ascribed to inflammatory action, or to a defective state of the circulating apparatus of the organ; it may be an effect of a defective or perverted state of the body generally, and it is frequently caused by post mortem agencies. Now these four varieties of softening, although, as regards their external appearances they have much in common, differ considerably from each other, each having peculiar attributes. The first and second varieties are generally found in the most, and the third in the least, vascular parts of the brain. Post mortem softening occurs, for the most part, in the immediate neighbourhood of the ventricles, is usually very diffused, is found on both sides at once, and is, of course, never preceded by symptoms.

Softening of the brain may be partial or general, and may present various degrees: the least change of consistence is only to be recognised by the microscope; in a more advanced degree the softening is obvious to the unassisted senses, at first to the touch and then to the eye, the diseased part being pultaceous, and readily removed by a stream of water, a cavity surrounded by healthy structure being made evident.

In a more advanced degree still, the cerebral substance instead of being pultaceous is quite diffluent, and occasionally a perfect solution of continuity is found. The softened portion of brain presents various alterations of colour. In inflammatory softening, the colour mainly depends upon the previous quantity of blood in the part; it may be of a deep red colour, with or without effused clots of blood, and frequently merges at the edges into at first a deep, and then a pale, yellow colour. Sometimes the yellow colour is central and the reddened portion external, resembling a collection of pus, so much so that Lallemand described it as such.

A dull red ochre colour with more or less hardening in the neighbouring structure, is indicative of chronic disease of long standing; as is also a chalky milk appearance, and a bright vermilion, of a recent effusion of blood into a previously softened part. In commencing softening, a diffused blush, with or without spots of blood, is generally found. A deep grey colour and fawn and dirty white tints accompany inflammatory softening, but much more frequently that which is produced by a deficient supply of blood.

No alteration of colour takes place in post-mortem softening.

These distinctions of colour indicate no essential differences, as far as structure is concerned, for all coloured softenings may present the same histological characters. As a general rule, the red varieties are indicative of acute inflammation, yellow of subacute, and white or grey of deficient nutrition of the affected part; but this rule is by no means invariable.

Universal softening of the brain, accompanied by a smell of sulphuretted hydrogen, is found in children suffering from general debility, and occasionally in infants stricken with induration of the subcutaneous cellular tissue.

Softening from a defective state of the circulatory apparatus is found, for the most part, in persons advanced in life, and constitutes what is termed *white softening*. It depends on the presence of osseous, cartilaginous, or atheromatous matter in the walls of the arteries, nearly or quite blocking up their entire caliber, and affecting vessels of all sizes. It may supervene upon occlusion of the common carotid from ligature, and, indeed, upon any circumstance retarding or diminishing the quantity of blood to the brain; intense inflammation may disorganise the vessels, carrying blood to a remote portion of the brain, and thus cause softening; or a severe blow, or the presence of a tumor of greater or less density and magnitude, may act in the same manner.

The very fact of adventitious products being found within the arteries, hints at a perverted state of the brain and system generally; absorption does not progress in the diseased portions of the brain, which, having lost their supply of blood, are in a state analogous to that of an extremity attacked with gangrena senilis.

The softening of the brain which is produced by post mortem agencies is of very frequent occurrence. It may exist alone, or may complicate the other varieties, and is caused by the decomposition natural to organised bodies after death, or by the infiltrating action of fluids, which, either during life or in the agony of death, were effused into the ventricular cavities, and sub-arachnoid spaces.

Softening of the spinal cord is of not uncommon occurrence. It presents the same characters as those pertaining to the like affection of the brain, is produced by the same causes, and offers the same pathological characters. Softening of the whole cord may occur, but most frequently parts of it only are affected; it is found softened most frequently in the lumbar region, and not unfrequently in the cervical.

Induration of the brain may be general or partial, and presents three degrees of consistence. In its first degree, the affected part is nearly of the consistence of a brain which has been left some time in dilute nitric acid; in the second degree, the indurated part is of a cheesy, and in the third of a waxy, fibro-cartilaginous hardness. General induration affects either the whole or the greater part of the brain: the degree of hardness never exceeds the first variety. The induration is not always equal throughout the whole of the parts affected, the central medullary parts usually exhibiting a higher degree of it than the grey substance. A section of the indurated portions generally presents increased vascularity, in the usual speckled and striated form; yet the reverse is occasionally observed, the brain being preternaturally white.

Induration of the spinal cord may be general or partial. Billard found a spinal cord in a child of a few days' old, which, without the membranes, supported a pound weight. In partial induration, the white, and not the grey, matter is usually affected. For further remarks on the softening and induration of the spinal cord, see the article NERVOUS CENTRES (Abnormal Anatomy).

Softening of the heart occurs as a diminished state of the cohesion of the muscular structure. It is a rare disease, and is produced by very opposite causes; from inflammation, from a defective state of the nutrition of the organ, with or without general anæmia, and from a perverted state of the nutrition of the muscular and cellular elements. The heart when softened collapses on itself when empty, tears with the greatest facility, and breaks down with little pressure, the finger perforating its substance and penetrating into its cavities with great ease. Its colour varies, being sometimes deep red and violet, at others dirty white, and occasionally of a faint yellow hue. Softening of the heart may be general or partial, superficial or deep-seated; it may be confined to the walls of a particular cavity, or to the ventricular septum, or it may occur in small patches, disseminated in the midst of the muscular substance. Softening of the heart may coincide with hypertrophy of its walls, or a dilated state of its cavities, and Hope found it in a case of angina pectoris.

When found as a sequel of carditis, the softening is of a dark tint, the fibres are dark from the whole heart being gorged with venous blood, soft and loose in their texture, being easily separable, and compressed with facility between the fingers. When accompanying chronic carditis and co-existing pericarditis, the white colour predominates, sometimes being nearly superficial, and attended by pericardial and sub-pericardial effusion.

The yellow-coloured softening is found in cases of local and general anæmia, in malignant fevers; and it sometimes has an inflammatory, as well as merely cachectic origin. An abnormal deposition of adipose tissue in the cellular structure of the heart, produces softening by affecting the nutrition of the muscular fibres, which suffer also from the state of system peculiarised by the above deposition.

Induration of the heart is said to follow carditis, and appears to be produced by the effusion of lymph into the cellular tissue, around the muscular fibres and beneath the serous membranes; by its contraction and subsequent hardening, it may pass into a substance almost equal to bone in hardness.

It may exist in any part of the organ, the whole of the apex and the columnæ carneæ of the left ventricle were found indurated in one case, and in another the walls of the ventricles were tough, did not collapse, and emitted on being struck, a ringing hollow sound. We sometimes find partial softenings and indurations in the same heart.

Softening of the lungs generally depends upon the presence of effused products of inflammation; for instance, in the engorged, hepatised, and suppurative stages of acute pneumonia. It is worthy of remark, that, although in the hepatised stage the lungs are heavier, contain less air, and appear denser, still they are more fragile, and on being pressed by the finger break down. The more acute and recent the inflammation, the greater the softening. When we press a healthy lung with the finger, it gives to the touch on account of the elastic state of the tissue; but this is lost, and an unusual resistance, easily broken through, is produced by the loss of air, and the presence of lymph, compound granule cells, serum, and an abnormal quantity of blood.

In the third stage of pneumonia, softening is produced by the alterations in the effused products; lymph, for instance, is converted into a yellow friable matter, which subsequently becomes pus. In typhoid pneumonia the softening is great, even in the first or congestive stage.

Softening of the lung may be produced by an insufficient supply of blood. A part of a lobe may be so indurated, that the vessels and bronchial tubes passing through it become blocked up; the tissue which ought to have been supplied by these becomes at first soft, and finally gangrenous.

Induration may occur in any part of the lung, it may affect simply the bronchi and the tissue in their immediate neighbourhood, or the interlobular cellular tissue and the parenchyma may suffer.

The bronchi after long continued and repeated attacks of inflammation are found in a more or less indurated state, the hardening being generally in the outer cellular coat, and the cartilages of the larger tubes may become as hard as bone. The lung in the vicinity is generally denser than it should be.

The interlobular cellular tissue may be hardened at the same time as the lobules, or separately; it becomes more apparent than usual, and acquires a density occasionally resembling fibro-cartilage, and sometimes exercises so compressing an influence on the lobules, as to obliterate them.

But it is as a sequel of inflammatory action of long duration, that hardening of the whole or part of a lobe is found; the vesicular structure first suffers, the air vesicles are obliterated, and, often enough, the bronchi and blood-vessels of a certain magnitude.

Such portions of lung are dense, not at all friable, possess a peculiar crispness, and contain little or no air.

The colour of an indurated lung may be light or dark grey, or brown, and rarely pale.

A section of a piece of indurated lung shows the circular apertures of the bronchi and larger blood-vessels, surrounded by a dense tissue in which no vesicular structure is seen. The fibrinous dense lymph which produces these changes frequently becomes the nidus for tubercular deposit.

Partial indurations are found around tubercular cavities and abscesses, and around collections of miliary, or of larger tubercular masses.

In certain obstructive diseases of the heart the circulation in the lungs is so impeded, that effusion of blood, constituting pulmonary apoplexy, or effusion of lymph, producing general increase of density of the whole lung, may occur.

Long continued pressure by a pleuritic effusion, has the effect of rendering the lung nearly solid and impervious to air.

In treating of alterations in the cohesion of *mucous*, *serous*, and *articular membranes*, it is necessary to premise that they consist of a basement membrane sustaining epithelium cells and supported by sub-basement areolar tissue in which vessels, nerves, and absorbents, are found.

The nutrition of the basement membrane and the proper development of the epithelium cells depend upon the amount and health of the fluid parts of the blood supplied to them by the capillaries of the sub-basement tissue. It is evident that any morbid state of this tissue will influence the integrity of the basement membrane and the epithelium cells; and it is known that, for the most part, physical alterations of these last depend upon such morbid states, and that these changes are most likely to happen where the cellular structure is loose and considerable in amount.

Softening has been found in all serous and fibro-serous membranes, and may be produced by inflammatory action and by a defective and perverted state of the general nutrition of the body.

The *lining membrane of the heart* is frequently softened, being at the same time redder and more vascular than usual. It is occasionally so soft as to peel very readily from the muscular structure; a like state of the *pericardium* exists with effusion of pus into its cavity. Softening of the *internal membrane of the venous system* is found of either a deep red or pale colour; the tissue is very lacerable and breaks down into a pulp under the scalpel; it may be caused by phlebitis, by the pressure of a considerable column of blood, especially when the valves have been obliterated; and is found in cases of malignant fever, scurvy, and whenever the fluids are greatly altered. Post mortem softening is frequent enough to raise our suspicions, and great allowance must be made for the macerating and colouring properties of the blood.

Chronic softening of the *internal membrane of arteries* is occasionally found; when so affected the serous tissue is easily lacerable, and such solutions of continuity are determined by causes, which ought in health to have no influence. Portions of the interior lining membrane may be found retracted and rolled up within the canal, so that with the effusion of lymph which generally occurs at the same time, and the consequent coagulation of a small portion of blood, the artery may become completely obstructed and obliterated in a part of its course. Occasionally, the arteries of the upper and lower extremities become thus affected in succession, on the employment of the slightest exertion, indicating a very extensive affection of the nutrition of the arterial system. We find, in cases of anæmia, and where atheroma is being deposited, considerable diminution of the general tenacity of the large vessels.

Softening of the *arachnoid*, *peritoneum*, and *pleura* is generally found where there is effusion of pus, or blood into the sub-basement tissue; it rarely occurs when lymph is thrown out into the serous cavity, but seems to be a more advanced phenomenon of inflammation, or, rather, is produced by inflammation of a more intense and destructive character.

Dalmas ascribes nearly all serous softenings to diseased states of the subserous cellular tissue, and we find constantly that on account of the altered state of this cellular structure, the peritoneum and pleura may be stripped off large spaces of the parts they cover; it is notorious, that in the pelvis sero-sanguineous effusion into the subserous cellular tissue, and consequent lacerability of the serous membrane, frequently occur. Pulpy degeneration of synovial membrane is a kind of softening with a perverted state of the nutrition of the tissue.

Softening of mucous membranes is generally produced by inflammatory causes: it is most frequently noticed, and is best studied, in the alimentary canal, part or the whole of which may be affected; it is most frequently observed at the end of the ilium, in the depending portion of the colon, and in the cæcum; in the right and left hypochondriac regions, and in the sigmoid flexure.

Softening of the mucous membrane in general, or of any one or more of its elements in particular, presents various degrees. In the first degree, the mucous membrane, instead of possessing that degree of cohesion which permits of its being detached from the submucous tissue, breaks as soon as it is seized between the fingers or blades of the forceps; in the second degree, the edge of a scalpel, or the finger, pressed lightly over its surface, converts it into a soft and somewhat opaque creamy looking pulp; and, in the third stage, it is so soft that it is removed with ease by a slight stream of water. In this stage portions of the mucous membrane are found partially or entirely destroyed, and having been removed by the fluid contents of the stomach or intestines, as the case may be, during life, the submucous cellular tissue is thus found destitute of its natural covering. It is in this manner that various forms of softening are produced, as irregular or circular patches of various sizes. It is important to notice this circumstance, for, when the softening is limited to the glandulæ solitariæ, as is frequently the case in dysentery, it might be overlooked; these bodies being very small, and their entire destruction by softening being often unaccompanied by any obvious alteration of the mucous membrane itself, the seat and nature of the intestinal affection might not be ascertained, were it not for the presence of a number of minute circular patches, which, when narrowly examined, are found to be the result of softening of these follicles; for it often happens that enlarged follicles are seen intermixed with the patches, and which, when a scalpel is carried over the surface of the mucous membrane, break down or are removed, and thus other patches are formed similar to the former. These circular patches, which have the submucous tissue for their base, are often described as ulceration of the mucous membrane; but in all cases of doubt, the scalpel, used as above, will enable us to determine their nature.

Softening of the mucous membrane in the form of stripes and bands, has been described with great care by Louis, and has been much insisted upon as a characteristic of inflammatory softening; but Carswell has proved its origin from post mortem causes.

Softening of the mucous membrane of the digestive organs, may present various degrees of redness, or it may be quite pale; the redness may be confined to the softened part, or it may extend to the neighbouring parts at the same time; or the latter may be red and the former pale.

The redness of the softened membrane may vary from a light or a dark red to a brownish or purple; varieties of colour the value of which it is by no means easy to estimate, inasmuch as the quantity of blood in an inflamed tissue cannot be taken as a measure of the degree of inflammation which had caused the accumulation of this fluid.

The pale softening presents also some variety of tint. The softened tissue is either of a pale greyish or yellowish grey tint, being little altered from its natural colour; or it may be paler than natural, when it generally presents a milky aspect, owing to the colour of the submucous tissue being seen through it.

The pale softening is found in pthisis, in tubercular disease of the mesenteric glands, and in any disease accompanied by great emaciation.

Softening may be accompanied by thickening of the submucous tissues, and may precede and surround ulcerations.

The inflammatory softening of the other mucous membranes resembles as closely as possible that which has been described; it is not however so frequently complicated with post mortem effects, nor does it so often occur, except in the œsophagus, stomach, and intestines from the action of irritant poisons, which produce it either by their direct action, or by inducing and modifying inflammation.

Softening of mucous membranes from post mortem causes, is of great importance as a pathological fact, and may be produced by the action of the secretions of the membrane itself, or by putrefaction. This last cause is of doubtful efficacy; it is not likely to be met with in post mortem examinations, made at a reasonable period after death; it may however suffice to cause complete decomposition, when the membrane has been the seat of disease before death, and more particularly when the lesion has been of such a kind as to deprive the tissue of its vital properties suddenly. General putrefaction rapidly occurs in many cases of sudden death, especially in those in which the nervous system, or blood, or both, happen to be the vehicles of the destructive agent.

Softening from the action of special secretions may occur in two manners, either by simple maceration, which is long in taking place, or by chemical action. The first may happen in all mucous membranes, the second in the stomach and intestines alone.

Under favourable circumstances, and at a greater or less period after death, we find softening of the coats of the stomach, perforation, and the contents of the viscus free in the cavity of the peritoneum.

Various opinions have been given by the most celebrated pathologists, to account for this phenomenon; some embracing the views of Hunter, and recognising a chemical and post-mortem cause; and others attributing it to certain inflammatory causes, which produced ulceration and subsequent perforation.

Now, Hunter's view is demonstrable by direct experiment, whilst that held by the others is disproved by the absence of symptoms during life sufficient to account for such vast organic changes, and by the difference between such ulceration and those solutions of continuity which we are now about to describe.

The following facts tend to strengthen the first, and militate strongly against the latter opinion. When a rabbit, dog, cat, or any animal, in fact, is killed an hour or so after a meal when digestion is going on, and is allowed to remain in one position and in a moderate temperature, we find, after a few hours have elapsed, that the mucous membrane of the most depending part of the stomach is softened, and can, with the submucous cellular tissue and the muscular coat, be broken down with the greatest facility. The vessels ramifying in the softened part are black from the action of the solvent upon their blood.

After a greater lapse of time we find the peritoneum perforated, and the contents of the stomach in its cavity; by and by the tissues in the immediate neighbourhood of the stomach begin to suffer, and we see the abdominal muscles, and the cuticle covering them, eaten through by the gastric juice.

In fish, softening and perforation occur so rapidly, that, unless perfectly fresh specimens be used, no microscopic structure can be distinguished in the stomachal mucous membrane. I have noticed the same thing to occur in caterpillars: their stomachs, which contain both globular and columnar cells, after a time become softened and are perforated, so, subsequently, is the external cuticle; nature seems to have taken this original method of doing away with useless organisms.

In ulceration of the stomach the affected part is generally circular, and if it reaches the peritoneum excites inflammation in the reflexion contiguous to it; by this means perforation is rarely accomplished. Now, in post mortem perforations the softened part, said by some to be the seat of ulceration, is diffuse and the perforation large and irregular, and no part of the neighbouring peritoneum presents the slightest trace of recent inflammation; shreds of muscular tissue and cellular membrane, moreover, form an irregular fringe around the opening, and, by their presence, detract greatly from the theory which calls such phenomena pathological and not pseudo-morbid.

Generally speaking, the fundus is most frequently the part of the stomach most affected by the gastric juice; but every thing depends upon its being the most depending part, and upon its containing more or less semi-digested food.

The solvent matter is secreted by the tubes of the stomach, and consists of pepsin in combination with lactic acid and water: it possesses the power of disintegrating all dead structures, but cannot influence the living tissues. It is not secreted when the stomach is empty, a stimulus to the mucous coat, in the form of some matter foreign to the stomach, is necessary for its production; it is probably the case, that an ulcer of the mucous membrane may act as a stimulus, and that a certain quantity of juice may always be present in the stomach; and that when, by the depressing effect of this lesion, the general nutrition suffers and the tissues are less able to resist decomposition, the gastric juice may act locally on the surface of the ulcer, and produce perforation before any peritoneal adhesion is formed. Perforation of the coats of the stomach sometimes occurs suddenly after a meal; it is produced generally by the giving way of some small ulcer, the progress of which had been enhanced by the presence of a large quantity of corroding liquid.

Post mortem softening may modify and exaggerate softening from other causes, and differs in its own appearances under various circumstances. The colour which the softened membrane presents appears to depend upon the quantity of blood contained in the organ at the time of death; if the quantity be small and natural, the softened parts are of a dull yellow or orange tint; and this colour increases with the quantity of the blood, and is accompanied by a black colour of the vessels. In infants and young children, and in anæmic patients and persons whose blood is deficient in quantity and altered in quality, containing a great disproportion of serum, the whole stomach appears as if macerated; it is, indeed, sometimes infiltrated with serosity, and is so completely deprived of blood that no trace of this fluid is perceived except in some of the larger veins.

Post mortem softening and perforation of the intestines may occur from the presence of an acid fluid, either within them or without, and derived from the stomach; in the one case, softening is from within outwards, and, in the other, from without inwards.

Softening of the skin: the skin may be softened wholly, or one or more of its layers only. In some skin diseases, especially among scrofulous subjects, there is an alteration of the cohesion of the epidermis, which is properly formed by layers of cells, the row nearest the basement being smallest and more liquid than the others, the more distant being dry and united laterally, so as to form a dense integument. Certain defects in the quantity and quality of the fluid contained in the newest made cells prevent them from progressing, normally, in their development; they do not become dry, neither is any disposition evinced by the basement to secrete other cells; under these circumstances the epidermis is soft, and the basement tender and red, the tissue beneath being visible.

The cutis may lose its consistence in several manners. When considerable quantities of serum are collected in the subcuticular cellular tissue, the cutis becomes mechanically distended and remarkably soft; and sometimes is only represented by a thin friable tissue, which breaks down with the least pressure. It may gradually lose its fibrous structure and degenerate into a tissue analogous to that usually found beneath it.

Softening also occurs as a sequel of acute active local congestion.

The *appendages of the skin*, the nails, hairs, and, in the lower animals, horns, undergo softening to a certain extent in diseases of long standing, attended with great emaciation; and softening of the *cornea* with ulceration is a common symptom of starvation.

Induration of mucous membranes, is generally caused by long continued sub-acute inflammatory action; the sub-basement cellular tissue is generally affected, and thickening of the whole structure, with hypertrophy of the papillæ, where they exist, is found at the same time. Induration with hypertrophy is consequent upon chronic dysentery, and upon chronic inflammation of the bladder. Ulceration of mucous membrane is generally accompanied by surrounding thickening and induration, and this last is frequent in the gall-bladder, gall-ducts, uterus, and urethra. Induration of mucous membranes is generally accompanied by contraction of their caliber or surface, — from the consolidation and subsequent contraction of lymph effused into the cellular structure. Fatal stricture of the intestines is produced in this manner, and so are urethral strictures. Ulceration of the stomach when healed, is followed by contraction of the cicatrix; and when the ulcer has extended into the duodenum from the stomach, pyloric constriction of the severest kind occurs. The colour of indurated mucous membrane is generally paler than natural: the opposite may occur, and the degree of density varies from a slight increase to a bony hardness.

An *indurated* and thickened state of the *membranes of the brain*, *pericardium*, and *pleura*, are found after long continued chronic inflammation, either of the membranes themselves, or of the parenchymatous structures in their vicinity. Effusion of lymph behind serous membranes always tends to their becoming harder and thicker than natural; after a while the lymph becomes organised and contracts, and produces a puckering and irregularity of the membranes. We find thickening and induration of the pleura over large tuberculous cavities, the peritoneum covering the liver, and intestinal canal, and in the sacs of old herniæ. Constriction of any part of the intestinal canal, and also of the pylorus, may be produced by sub-peritoneal effusion of lymph.

Softening of the liver usually occurs in a manner not to be appreciated by the eye, being simply easily broken down under the finger; occasionally, however, the liver looks as if it had been macerated for a great length of time in a dark fluid, its texture has completely lost its cohesion, and has become in certain spots quite diffluent. Livers in a state of softening may retain their ordinary colour, or it may be increased, and even decreased, in an extraordinary manner; for, sometimes, no traces of blood can be found, except in the larger venous trunks, and the tissue of the liver is pale and light drab in colour. Softening of the liver is found frequently on the anterior and convex surface, as a product of inflammation; partial and curable softening has been noticed to accompany inflammation of the right lung; and, finally, the consistence of the liver is much influenced by the abnormal deposition of fat, which sometimes occurs in the ultimate cells of the organ.

Induration of the liver is generally produced by the deposition of lymph, its subsequent contraction and its compressing influence upon the lobules. This effusion is the consequence of adhesive inflammation in the areolar tissue about the twigs of the portal vein, serum and coagulable lymph are poured out, the first is absorbed, and the latter consolidated, and ultimately converted into dense fibrous tissue, which divides the lobular structure of the liver into well defined masses, gives great density and toughness to the organ, by compressing the small twigs of the portal vein, and the small bile ducts, thus impeding the flow of blood and the escape of bile, and causing the usual yellow tint which accompanies this disease.

This deposition of fibrous tissue produces different effects according to the parts it principally involves. Sometimes the lymph is effused exclusively into the cellular tissue of the portal canals of considerable size, and if the person die some time after this has occurred, all the considerable branches of the portal vein are found surrounded, in some places, to the distance of half an inch, by new fibrous tissue, which by its contraction has drawn in and puckered the adjacent portions of the liver. The remaining portions of the liver may be little or not at all altered in texture, and may be readily scraped away from these indurated portions; the main branches of the portal vein are still pervious, but many of the small branches leading from them are obliterated, the parts which they supply atrophied, and the liver correspondingly diminished in bulk. When such portions are near the surface, the capsule is drawn in, thickened and puckered, and generally covered with false membranes.

In other cases, the fibrous tissue is not found around the larger veins, but in the vicinity of the small twigs that separate the lobules; all the substance of the liver is thus rendered tough; and when the organ is sliced, the fibrous tissue is seen to form distinct lines, between small irregular masses of lobules. At the parts on the surface of the liver which correspond to these lines, the capsule is drawn in, so that the organ presents what is termed a hobnailed appearance. The degree of hardness is determined by the amount of the adventitious tissue, and, as a general rule, the denser the organ, the paler its colour; ordinarily, the colour is pale grey, or resembles that of impure wax; and hence the term *Cirrhosis*.

Induration of the liver occurs around growths, abscesses, and hydatid cysts, and may be produced by inflammatory action of a specific or non-specific nature.

Softening of the spleen is produced by an altered state of the fluid which it contains naturally, and by inflammatory action, or by both causes. Softening produced by the first means is common in low fever, intermittents, and scurvy; the fibrous element of the spleen does not suffer; but the blood, which is contained within its meshes, loses its natural consistence, appears to lose its coagulating power, becomes dark, and is washed away, leaving the white fibres intact, by a slight stream of water. In softening from inflammatory action the whole tissue of the spleen is disorganized; it breaks down under the slightest pressure; the external fibrous envelope is much softer than usual; and its internal prolongation is totally destroyed. Both of these kinds of softening occur, with or without alteration, in the bulk and dimensions of the organ.

Induration of the spleen may also arise from an abnormal state of the blood, and from inflammatory action. When the consistence of the blood is altered, the spleen, which may or may not be enlarged, cuts like liver or frozen muscle; and no great quantity of blood follows the incision, the whole tissue being, in fact, denser than usual.

Inflammatory hardening may or may not be equal in degree throughout the whole organ; frequently, certain spots, the seat of old effusions of blood, are denser than the indurated tissue around them; and eccymoses and dark yellow and black spots, are found sometimes scattered over the hardened tissue. This variety of induration may be accompanied by increase or decrease of bulk, or no alteration in size may occur; in degree, it may vary from the slightest increase of consistence, depending upon excessive nutrition, to a bony hardness.

Softening of the kidney is of common occurrence, being frequently found, with an enlarged state of the organ, in several of the diseases comprehended under the term Bright's disease. It exists also in the kidneys of diabetic subjects, and in some cases of renal calculi. When produced by inflammatory action, the softened kidney is dark red, and when a consequence of a perverted state of the nutrition of the organ, it is usually of a pale colour. Generally speaking, the softened state is produced by enlargement of the uriniferous tubes, and a consequent diminution of the solid matrix, or this last only may be affected; and when such is the case, the tissue breaks down with the slightest pressure. In degree, softening may vary from simple flabbiness to a state approaching diffluence.

Induration of the kidney is generally found with an atrophied state of the organ; it is a sequel of acute, and is found in chronic, nephritis, especially in gouty subjects. In these the kidney is frequently indurated, paler than natural, less vascular, and many of its tubes may be blocked up with urate of soda. Induration is sometimes accompanied by an hypertrophied and a darkened state of the organ. In the first stage of induration, the consistence of the organ is slightly exaggerated, and the finger makes no impression on it; in such kidneys we find superficial star-like venous twigs, and more or less confusion of the cortical tissue. In a more advanced stage, the tissue may become nearly as hard as cartilage, and perfectly colourless. Portions only of the kidney may be affected, but, generally, the greater part of it suffers; and it is, comparatively speaking, rare to find cartilaginous induration of one or more of the mammilated processes.

Induration and softening of the uterus are frequently products of acute inflammation of the organ; the first is formed but slowly, the latter with great rapidity, and may or may not be complicated with effusion and infiltration of pus, into the muscular structure. Uncomplicated softening is frequently the result of a more chronic and subacute inflammatory action, and is occasionally found in the impregnated uterus, being made known to the practitioner by the spontaneous rupture of its walls, and the passage of its contents into the cavity of the abdomen. A softening, either general or partial, is found in cases where there were no uterine symptoms during life; the tissue is as friable as that of a softened spleen; but none of the products of inflammation are to be found. It is, probably, produced by a perverted and defective state of the general nutrition; the uterus, from its low vitality, prominently suffering. A putrid sloughy-looking softening occurs around growths and ulcerations of the uterine tissue.

Softening and induration of the ovaries are usually produced by acute or chronic inflammatory action: the one, if found in the early stages of ovaritis, is produced by the effusion of serum into the tissue of the ovary; and the other, a sequel of the same disease, is produced by the contraction and hardening of effused lymph.

In old age, thickening of the fibrous coat, and atrophy, and induration of the stroma, with special hardening around old Graafian vesicles, are very common: this state is frequently preceded by a flabby consistence of the organ.

In the puerperal state, the ovaries are subject to complete softening and disorganization; the natural structure is lost, and, in its place, is a pulpy diffluent bloody-looking mass.

An indurated state of the *prostate gland* is common enough in old age, and is generally accompanied by hypertrophy; and a grey or white hardening of the *testicle* and *epididymis*, with or without destruction of the seminiferous tubes, is frequently found as a sequel of chronic inflammation.

A softened state of the whole or part of the *osseous framework* of the body, is met with in scrofulous habits, and in persons suffering from cancerous cachexia, under the form of rachitis and mollities ossium. In the first of these diseases, there is a deficient deposit of earthy matter, and the animal matter is probably of an unhealthy quality; whilst in the second, the constituents are not deficient in quantity, but bad in quality, and the vital properties of the bone are completely deranged; the osseous structure has lost its cohesive power, and breaks with the least muscular effort. In rachitis, the bones may be bent in any direction, and are easily cut; their centre resembling cartilage. In mollities ossium, the knife penetrates the tissue, which appears to consist of numerous cells, with thin walls, and containing an oleaginous fluid, with the greatest ease. Occasionally, bones are found so softened as to resemble lard in consistence; and sometimes in subjects which have suffered from chronic disease, the ribs are more easily cut through than the cartilages. In caries, also, there is a softening and absorption of the bony texture, which crumbles away on the slightest touch.

Softening of cartilage is found under three forms. It may lose its usual elasticity and become doughy, or the usually dry and elastic cartilage of an adult may be found soft, as if it were that of an infant; it acquires extensibility, and its elasticity diminishes. Finally, the cartilage of adult life may so lose its consistence, as to resemble embryonic cartilage; it becomes pale and transparent, its quantity of solid matter being very small, and its proportion of water great, and the softness considerable.

Fibrous tissue resembles cartilage in its alterations of cohesion, and both are apt to become indurated by a deposit of osseous matter.

Softening of the muscular structures may occur, as a sequel of inflammation in the cellular tissue which surrounds and binds together the ultimate fibres; or as a result of long continued inaction, produced by loss of nervous influence, as in paralysis, or by long standing disease. Softened muscles are pale, flabby, and contain much fat; are incapable of long or severe action, and are deficient in irritability.

Softening of the muscles of organic life, generally depends upon an inflammatory condition of their neighbouring submucous or subserous cellular tissue.

Softening of cellular tissue is very common. It has already been noticed as occurring from effusion of serum, pus, and blood. These render it more palpable and more liable to be torn, and its simple lacerability is frequently set down to softening: it is difficult, however, to draw the line. A great consequence of softening of the cellular tissue, is softening of the subjacent and neighbouring tissues; we have noticed this to a considerable extent in softening of the sub-pleural tissue, and also of the submucous and subperitoneal tissue of the alimentary canal.

There is hardly any part of the body in which cellular tissue is not to be found; and consequently nearly all the tissues may be influenced by its softened state. The effusion of fluids into the areolæ of the cellular tissue, may follow inflammatory action or may be produced from a malignant or typhoid state of system, and from post mortem causes.

The colour of the softened membrane depends upon the nature of the effused fluid.

Induration of cellular tissue is generally caused by the effusion, and subsequent contraction and hardening of coagulable lymph; or the simple effusion may produce hardening, as in the immediate vicinity of old ulcers. However, it is notorious that even in this case contraction and consolidation occur at a little distance from the seat of irritation; in certain skin diseases, and in the cicatrices following burns, great injury may be effected by the contracting power of the effused lymph.

But it is behind mucous and serous, or serofibrous membranes, that induration from inflammatory action principally occurs, and leads to effects, most noxious to the general economy; strictures of the gullet, pylorus, intestines, and urethra, depend upon the submucous or subserous effusion and consolidation of lymph.

A hardened state of the mammary gland depends upon the same cause. Dense, crisp-cutting consolidations of cellular tissue, are frequently mistaken for scirrhus, and, indeed, are frequently the seat of morbid growths.

Induration of the cellular tissue may depend upon a perverted state of the general nutrition; in syphilis, for example, there is frequently subperiosteal effusion of lymph, which has a tendency to ossify. It is also very frequently brought about, and becomes cartilaginous in hardness, by long continued local irritation. We notice the indurated state of the tissue around scrofulous glands, and its condensed form around miliary tubercles. The disease, which has been termed hardening of the cellular tissue, occurs in infants. The subjects of this disease are, for the most part, feeble, sometimes imperfectly developed, and generally born before the full period. It is a disease seen, for the most part, in hospitals, and is found where filth, bad ventilation, and worse food abound; consisting, in a wax-like hardness of the subcutaneous cellular tissue, and is produced by the effusion of a sero-albuminous fluid into its meshes. This effusion produces swelling of the affected parts, as well as hardening; and occurs, first of all, in the inferior extremities, passes from the feet upwards, and subsequently attacks the hands, arms, and then the trunk itself.

The hardened limbs are dry, cold, and may or may not pit on pressure; their colour is either unchanged, or has a dull yellow or a lived hue. Symptoms of obstructed respiration supervene before death.

When a section of an affected limb is made, and the subcutaneous cellular tissue is well exposed, we find its cellular appearance much increased, from the interstices being filled with a fluid, which is either limpid, or more concrete, and of a citron colour, or tinged with blood. The quantity of this fluid determines the degree and amount of induration; and occasionally the fatty structure beneath the skin is hardened from the compressing influence of the effusion.

It is very doubtful if the effused fluid becomes wholly concrete. Chevreul says, that the serum of the blood, in infants affected with hardening of the subcutaneous cellular tissue, contains a large quantity of a spontaneously coagulable matter, analogous to that which is effused into the affected tissue. Great and general venous congestion is always found in these cases, and would seem to depend on insufficient vital energy, produced by the depressing influences of damp, bad nourishment, and cold.

For some particulars respecting the Softening and Induration of " Growths," see article on Adventitious Products.

(*P. Martin Duncan.*)

SOLIPEDA. Syn. *Solidungula, Pachydermes Solipedes.* — An important group of herbivorous quadrupeds, regarded by Cuvier as constituting a third family of his order Pachydermata, and defined as " animaux à sabots non ruminans," or non-ruminant, ungulate quadrupeds. They form, however, a race of animals that presents many remarkable peculiarities of structure, and, from their great importance to mankind, demand, in a work like the present, a somewhat minute description of their anatomy and general organisation.

The Solipeda, zoologically considered, comprehend but the single genus EQUUS, at once distinguishable from all other quadrupeds by the remarkable construction of the anterior and posterior extremities, each of the four feet appearing externally to consist of but a single toe enclosed in a solid hoof of horn, although, within, there are found concealed beneath the skin the rudiments of two other digits, appended to each side of the metacarpal and metatarsal portion of the limb.

The genus EQUUS is further characterised by the following peculiar disposition of the dental apparatus: — There are six sharp and trenchant incisors both in the upper and in the lower jaw, and an equal number of grinding teeth, the crowns of which are of a square form, each having its surface intersected by deep plates of enamel, arranged in the shape of four crescentic masses, in addition to which there exists in the teeth of the upper jaw a small disc of enamel, situated upon the inner border of each tooth.

The males have, moreover, two small canine teeth developed in the upper jaw, and sometimes in the lower one also; but these canine teeth, or *tushes* (tusks), as they are generally called, are for the most part altogether wanting in the females. A considerable interspace exists between the canine teeth and the first molar, so that that portion of the mouth of the horse which is opposite to the commissure of the lips is devoid of any dental armature, a circumstance of which man has availed himself for the purpose of introducing into the mouth of these animals that bit by the aid of which he is enabled to subjugate his steed, and thus secure to himself the services of an assistant not less conspicuous for his indomitable strength than for his matchless docility. The stomach of the Solipeds is simple in its form, and of moderate dimensions, but their intestinal canal is of very great length, and the cœcum and colon enormous in their proportionate size.

Thus characterised, the genus Equus is found to comprehend several different races of quadrupeds that are generally regarded by modern naturalists as constituting so many distinct species. These are — 1st. The Horse (*Equus Caballus*), "man's noble companion in the chase or on the battle-field, in the labours of agriculture, in the arts, or in commerce." The original country whence the horse has been disseminated through the whole world has now become a matter of uncertainty, although most probably the wide plains of eastern Europe and of Asia, where wild horses still abound, may be pointed out as their central station. That they were in common use in Egypt from the very earliest period of which we have any record, is evident from the sacred writings (*vide* Gen. c. xlvii. v. 17., and c. l. v. 9.), and hence it is supposed to have been derived by the Arabs, Persians, Ethiopians, Indians, Parthians, Scythians, &c. At the present day, wild horses are by no means common even in their native regions, owing to the encroachments of man upon their original haunts; but, on the other hand, they have spread over the vast prairies of the new continent, and may now be said to be as extensively distributed as the human race itself.

The second species admitted by zoologists to form a distinct race is the Dzigguetai (*Equus Hemionus*), intermediate in size between the horse and the ass, from both of which it is distinguished by its colour, which is light bay, with a black mane and dorsal line, and it also has a black tuft of hair at the end of its tail. This animal is found in large troops among the sandy plains of Central Asia.

3d. The ass (*Equus Asinus*), at once recognisable by the length of its ears, by the tuft of hair at the end of its tail, and by the black cross upon its shoulders, which is the first appearance of those transverse bands which become numerous in the succeeding species. This animal seems to be indigenous to the desert regions of Central Asia, where vast troops of them still abound in a wild state.

4th. The Zebra (*Equus Zebra*), a native of the southern regions of Africa, and conspicuous for its symmetry and the alternate transverse stripes of black and white with which its skin is all over marked.

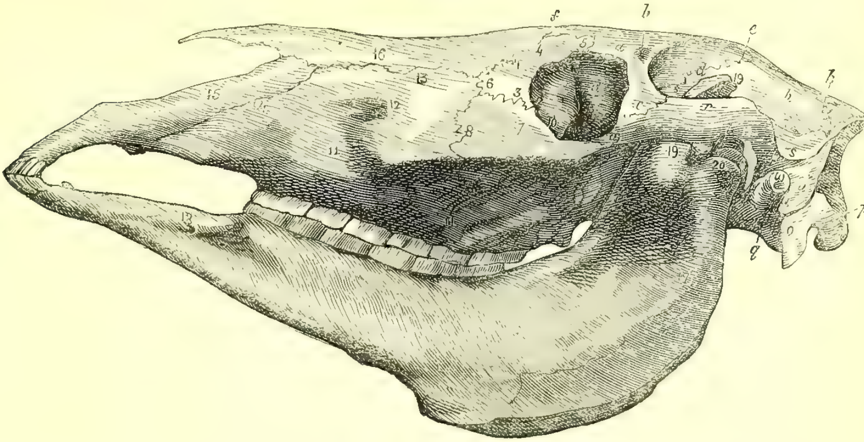
5th. The Quagga (*Equus Quaccha*), a native of the same regions as the Zebra, from which it principally differs in the colour of its skin and more horse-like appearance. Its hair upon the neck and shoulders is brown, marked transversely with white stripes; its croup is of a greyish-red colour, while the tail and legs are white. The name of this animal is derived from its peculiar voice, which somewhat resembles the bark of a dog.

6th, The Onagga, or Dauw (*Equus montanus*), is somewhat less than the ass, and in its shape resembles the quagga. Its general colour is a light bay marked with black stripes, that are alternately broader and narrower over the head, neck, and trunk; the hinder stripes are directed obliquely forward, while the legs and tail remain white.

With respect to their anatomy, it may be observed, that all the above species resemble each other as closely in their internal economy as they do in outward form, and accordingly, in the following pages, we shall confine ourselves principally to a description of the horse, as being the typical species of the group, noticing, however, incidentally, such peculiarities of structure as may be worthy of remark in the humbler congeners of their noble prototype. So near, indeed, is the relationship between the different members of the entire genus, that they will breed together without difficulty, although the progeny of such a union, the mule, is generally incapable of reproduction. Such is well known to be the case between the horse and the ass, as also with the zebra, and doubtless with the genus generally.

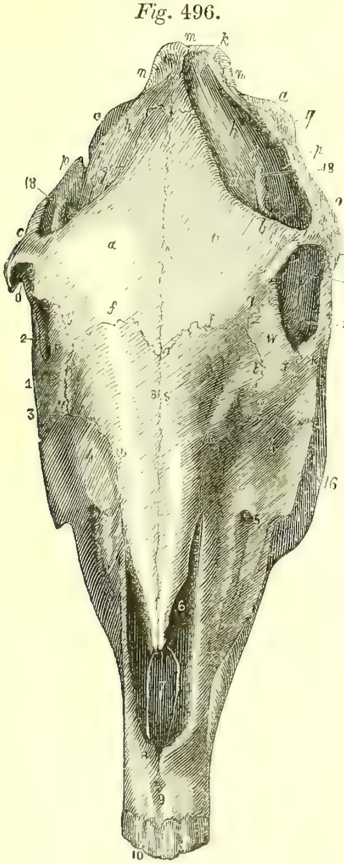
Osteology.—*Skull.* The head of the horse is at once recognisable by the following characters*, namely, by the great enlargement between the orbits (*fig.* 496. *a a*), by its slightly

Fig. 495.



a, b, c, d, e, f, os frontis; *b,* supra-orbital foramen; — *h, i, k,* parietal bone; — *l, o, p, q,* occipital bone; *l,* occipital protuberance; *p,* condyle; *o,* paramastoid process; *q,* basilar portion;—*r, s, t, u, w, x,* temporal bone; *r,* zygomatic portion; *x,* suture with the malar bone; *t,* glenoid cavity; *u,* mastoid process; *w,* tympanic ring;—1, 2, 3, 4, 5, 6, lacrymal bone; 2, position of the nasal duct; — 7, 8, 10, malar bone; — 11, 11, 12, 13, 14, superior maxillary; 12, infra-orbital foramen;—15, intermaxillary;—16, nasal bone; — 17, 18, 19, 19, 20, inferior maxillary; 18, mental foramen; 19, 19, coronoid process; 20, condyle.

Fig. 496.



A, a, a, b, c, c, d, d, f, f, g, g, frontal bones; *A,* frontal suture;—*h, h, i, i, k,* parietal bones; — *m, n, n,* occipital; — *o, o, o, p, q, r,* temporal bones; *o, o, o,* zygomatic processes; *r,* suture with the malar; — *s, s, t, u, u,* nasal bones;—*w, x, y, z,* lacrymal bone;— 1, 1, 2, 2, 3, 3, malar bones; — 4, 4, 5, 5, 6, superior maxillary bones; 5, 5, infra-orbital foramina; 6, palatal process; — 7, 8, 9, intermaxillary bones; 8, nasal process; 7, palatal suture; 9, foramen in the suture; 10, incisor teeth;—16, 18, 18, inferior maxilla; 18, 18, summits of coronoid processes.

convex profile, by the length of the face, which is more than double that of the cranium, and by the vertical depth of the lower jaw, which is more than that of the whole cranial portion of the skull. The temporal ridges, prolonged backwards from the post orbital apophyses, extend as far as the middle of the parietal bones, and there form a short sagittal crest upon the mesial line of the skull, whence, proceeding backwards, they diverge and extend as far as the occipital ridge, which is truncated above (as is the case in the pachydermata generally), and projects over the posterior surface of the occiput. The intermaxillaries are prolonged considerably beyond the nasal bones, which last, by their points, arch over the cavity of the nostrils to a considerable extent. The temporal arch is comparatively very short, nearly straight, and is situated entirely in the posterior third of the skull.

As regards the individual bones of the skull, it may be observed that the two *frontals* (*fig.* 496. *a, a, f, g*) remain distinct from each other after the parietals become consolidated into one piece; they are of remarkable breadth between the orbits, and posteriorly penetrate to a considerable depth between the parietal bones. The *ossa parietalia* (*fig.* 495. *h, i*) give off on each side of the cranium a pointed

* Cuvier, Ossemens fossiles, t. ii. p. 108.

process, which encroaches largely upon the squamous process of the temporal bone. The zygomatic process of the temporal (*fig.* 496. *o*) has at its base a process which projects upwards and backwards. This process constitutes the entire length of the temporal arch, articulating anteriorly by suture with the post-orbital process of the os frontis (*fig.* 495. *b, c*), which is very long: the zygomatic process of the temporal even extends to beneath the orbit, the bony circle around which it contributes to form, and is thence prolonged behind the *os malæ*, so as to become articulated with the superior maxillary bone. The occipital suture is situated considerably in front of the superior occipital ridge; nevertheless there is generally an interparietal bone of quadrangular shape, called by hippotomists the *os quadratum*, but which at an early age becomes consolidated with the two parietals. The interparietal is, indeed, itself frequently divided into two pieces in the new-born foal. It is always much too narrow to reach as far as the temporals.

The anterior sphenoid appears but very slightly in the orbit. The posterior sphenoid mounts upwards in that region almost as high as the temporal, but without coming in contact with the parietal. Inferiorly, it is prolonged in a square form considerably beyond the pterygoid region. The glenoid cavity for the articulation of the lower jaw is situated beneath the middle of the temporal arch; it is convex inferiorly, and has a tubercle situated behind its internal extremity, behind which, and on the same level, is situated the *meatus auditorius externus*. The bony meatus remains distinct from the temporal even when it has become completely consolidated with the tympanic and petrous portions of that bone. The tympanum is but little prominent, and of a very irregular shape. The petrous portion appears externally at the side of the occiput (*fig.* 495. *u*), in front of the base of the para-mastoid apophysis (*fig.* 495.*p*),which is here long and pointed.

Of the bones of the face it may be observed, that the ascending apophyses of the intermaxillary bones (*fig.* 495. 15) are placed very obliquely, and become connected with the ossa nasi at about one third of the length of those bones from their anterior extremity. Inferiorly, their palatine apophyses penetrate between the maxillary bones as far as the first molar teeth, leaving two incisive foramina, or rather fissures, which are about half the length of the apophyses themselves. The pointed extremities of the ossa nasi arch over the cavity of the nose nearly as far as the middle of the intermaxillary bones. Superiorly, the ossa nasi increase in breadth as far as the inner angles of the orbits, where they become joined with the lacrymals (3, 4, 5, 6), which descend to a considerable distance upon the cheek, and enter almost as largely into the structure of the orbital cavity. The *jugal* (*fig.* 495. 7, 8) advances upon the cheek as far forwards as the lacrymal bone, and terminates beneath the middle of the orbit. This bone does not extend sufficiently far backwards to enter into the composition of the zygomatic arch, properly so called. It forms upon the side of the cheek, by its union with the maxillary bone, a broad, square ridge, which is continued backward as far as the commencement of the zygomatic arch.

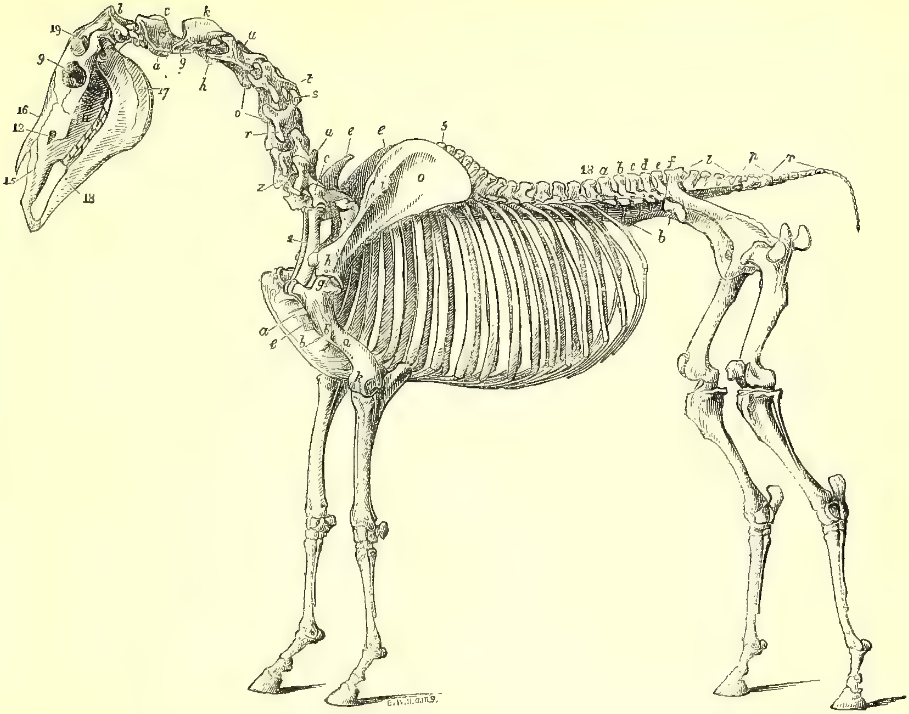
The palatine bone is deeply notched and very narrow, not extending forward beyond the penultimate molar tooth. This bone merely forms a narrow border around the meso-pterygoid fossa, but it composes more than two thirds of the pterygoid alæ. In the floor of the orbit it mounts upwards, between the maxillary bone on one side, and the two sphenoids on the other, as far as the os frontis, but it does not come in contact with the lachrymal. The external pterygoid process of the sphenoid runs along the palatine externally, and extends beyond it, but the internal pterygoid process is distinct from the sphenoid, forming a long and narrow tongue-like process, which, after having covered the lateral suture of the anterior end of the posterior sphenoid, extends obliquely over the centre of the pterygoid process of the palatine, and proceeds to form a bony hook, situated upon the side of the great palatine fissure.

Spinal column.—The *cervical vertebræ* of the horse are, as in all mammiferous quadrupeds, seven in number; their proportions are massive, and the whole series forms a chain of great strength and considerable flexibility. All the posterior vertebræ of the neck have in the horse a square or oblong shape, and both the spinous and transverse processes are short and stunted, so as not to interfere with that freedom and extent of motion which is essential in this portion of the spine.

The *atlas*, as in man and other mammifera, presents characters peculiar to itself. The body of this bone is entirely suppressed, its place being supplied by the two articulating surfaces appropriated to the reception of the condyles of the occipital: the superior lamina are broad and flat, and the superior spinous apophysis is not developed; whilst, instead of transverse processes, the vertebra is prolonged laterally into two broad alæ, into which numerous muscles are implanted. In the horse it may be remarked that the entrance of the canals for the passage of the vertebral arteries, instead of being situated at the posterior edge of the transverse apophyses, is placed upon its upper surface, but in other respects this bone presents no peculiarity worthy of special notice.

Axis. — The configuration of the second cervical vertebra in most quadrupeds differs considerably from what is met with in the human subject, owing to the horizontal direction of the neck, and the unfavourable position in which the head has to be sustained. This difference is most remarkable in the arrangement of the spinous process, which, instead of being merely a prominent tubercle, as in man, is prolonged into a vertical crest that

Fig. 497.



Skeleton of the Horse. (*After Stubbs.*)

Skull.—9, orbit ; 11, 12, superior maxillary bone ; 12, infra-orbital foramen; 15, intermaxillary; 16, os nasi; 17, 18, 19, lower jaw; 18, mental foramen; 19, coronoid process. *Cervical region.* — *a*, *c*, the atlas; *g*, *h*, *k*, the vertebra dentata; *o*, body; *r*, transverse; *s*, *t*, oblique, and *u*, spinous processes of cervical vertebræ ; *z*, process from the root of the transverse process of the sixth cervical vertebræ, assisting with its fellow to form the groove in which the longus colli muscle is lodged. *Dorsal region.*—*c*, oblique, and *e*, *e*, spinous processes of the two anterior dorsal vertebræ; 5 to 18, continuation of dorsal spinous processes. *Lumbar region.*—*a*, *b*, *c*, *d*, *e*, *f*, lumbar vertebræ; *l*, the sacrum; *p*, superior, and *r*, inferior, caudal vertebræ. *Sternal region.*—*a*, *b*, *c*, osseous and cartilaginous pieces of the sternum with the cartilaginous attachments of the true ribs. *Shoulder.*— *h*, *i*, *o*, the scapula; *b*, *g*, *k*, the os humeri.

sometimes advances forwards above the atlas and is prolonged posteriorly above the third, or even the fourth, cervical vertebra, thus affording an ample expansion for muscular attachments. In the Solipeds, this spinous crest (*k*) is but moderately developed, extending backwards so as to overlap the third vertebra to some extent ; but its anterior prolongation is wanting. The transverse apophyses are short, and perforated by the vertebral canal, while the articular processes are but moderately developed, and directed backwards to articulate with those of the succeeding vertebra.

The five posterior cervical vertebræ are remarkable for their strength and mobility ; their bodies are of great proportionate size, and articulated together by broad sub-globular surfaces that allow a considerable extent of motion ; the vertebral laminæ are broad and massive, and the articular processes well developed and connected together by large articulating surfaces. The spinous processes are almost wanting except upon the sixth and seventh vertebræ, that belonging to the latter being of considerable size and turned backwards, so as to represent the commencement of the dorsal series of spines. The bodies of the sixth and seventh vertebræ of the neck, more particularly of the former, are prolonged inferiorly into a central crest of considerable size, which projects downwards and backwards, and gives origin to the *longus colli*, which muscle is likewise lodged in a kind of groove formed by osseous plates derived from the transverse processes.

The *dorsal vertebræ* in the Solipeds are invariably eighteen in number, and are distinguished by the shortness of their transverse apophyses, each of which is provided with an articulating surface, whereby it is connected with the corresponding rib as well as by similar articulations situated on each side upon the anterior and posterior extremities of their bodies to which the heads of the ribs are affixed. The spinous processes of the anterior dorsal vertebræ are of great length, and dilated at their extremities, where they give origin to the broad elastic cervical ligament by means of which the weight of the head is in a very material degree supported; posteriorly, the spinous processes of the dorsal region become gradually shorter, and their extremities broad and flattened, so as gradually to approximate in their shape those of the lumbar region.

The *vertebræ of the loins* are, in the Solipeda, usually six in number: such is the case in the horse, zebra, and quagga; but in the ass there are but five lumbar vertebræ. This portion of the vertebral column is, in the class under consideration, possessed of great strength; the bodies of the vertebræ are broad and firmly bound together; the transverse processes of remarkable length and power; the articulating apophyses strong and broadly connected with each other, while the spinous processes, which are of great breadth, are either quite straight or inclined forward.

The *sacrum* in all the Solipeda is composed of five vertebræ consolidated into one piece, and, with that exception, scarcely different from the vertebral pieces that immediately precede and follow it. In the horse, as in most quadrupeds, the sacrum is much narrower in proportion than in the human subject, and forming, moreover, a continuous straight line with the rest of the spinal column, allows of much more freedom of motion in this part of the skeleton than is possible in the human subject; and this is much increased by the obliquity of the junction between the sacrum and the iliac bones. The articulation, moreover, between the last lumbar vertebra and the sacrum, still further adds to the mobility of these parts; for in the horse, the oblique processes of that vertebra are connected with the sacrum by means of articulating surfaces of very large size, so that from the combination of all these circumstances, there is a springiness given to this region of the vertebral column, the importance of which, in galloping or leaping, is at once conspicuous.

The *caudal vertebræ* in the solipeds vary in number from seventeen to twenty-one; but of these, the upper ones only resemble true vertebræ. Even in the first caudal vertebra, the inferior oblique processes become obliterated, and as we descend, all the vertebral apophyses rapidly disappear: at the second bone of the tail, the spinal laminæ no longer rise high enough to enclose the spinal canal; but resemble two short processes; and at about the fifth or sixth, all vestiges of them are lost, nothing remaining but the bodies of the vertebræ of a cylindrical shape and slightly enlarged at each extremity, until we approach the last, where all regularity of form is lost.

Thorax. — The *sternum* of the solipeds is considerably compressed towards its anterior extremity, which is moreover prolonged to some extent beyond the insertion of the first rib, so as to give to the whole chest a carinated appearance, which forcibly reminds the anatomist of the thorax of a bird. Posteriorly, the carinated form disappears, and the sternum becomes broad and flattened where it receives the cartilages of the posterior true ribs. The sternum of the horse is composed of several osseous pieces bound together by strong ligamentous and cartilaginous connections.

The *ribs* are eighteen in number, so that the thorax is prolonged very far backwards towards the pelvis. The anterior ribs are broad and massive; but of these, eight only are attached to the sternum: the posterior or false ribs gradually become more slender as they recede backwards to expand over the cavity of the abdomen.

Anterior extremity.—The frame-work of the shoulder in the Solipeda, as in all ungulate quadrupeds, is composed of the scapula only; the coracoid apparatus being dubiously represented by a rudimentary apophysis, and the clavicle is totally wanting in circumstances which allow of the close approximation of the shoulder blades to the sides of the chest, and thus cause the weight of the body to be transmitted perpendicularly to the ground.

The shape of the *scapula* (*fig.* 498. *o*) is almost that of an isosceles triangle, the spinal costa, which is about half the length of the other two, having its angles rounded off. The spine of the scapula is prominently developed, and towards its upper third, projects posteriorly, so as to form a considerable recurved process (*i*); as it approaches the neck of the bone, however, the scapular spine becomes quite obliterated, spreading out upon the margin of the glenoid cavity (*h*), so that no acromion process exists in these quadrupeds.

The *humerus* (*fig.* 498. *e, b, k*) is short, but of great strength, and the muscular imprints strongly marked.

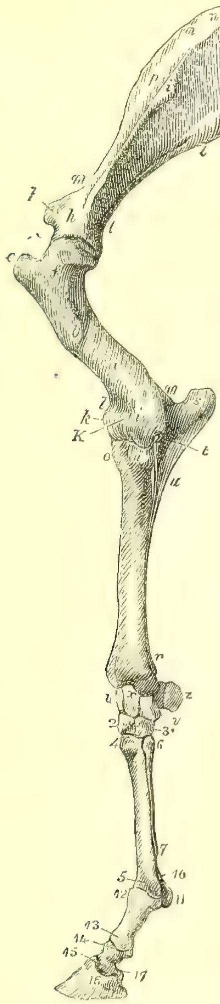
The *forearm* is almost exclusively formed by the *radius* (*fig.* 498. *o, r*), the strength of which is in accordance with the enormous weight it has to sustain, while the *ulna* is reduced to a mere appendage (*fig.* 498. *s, t, u*), which in the adult animal is completely consolidated with its posterior surface, the line of demarcation between the two being only indicated by a furrow which, towards the upper extremity of the forearm, deepens into a slight fissure. The olecranon process is, however, of large size, and, by its projection posteriorly, affords a powerful purchase to the massive extensor muscles inserted into this portion of the limb. From the above arrangement of the bones of the forearm, it is manifest that all movements of pronation and supination are here out of the question; the limb must remain constantly fixed in a state of pronation, in which condition it is anchylosed, and thus acquires a firmness and steadiness which would be quite incompatible with more extensive movements.

The *carpus* in the Solipeda consists of seven bones arranged in two rows, — of which four are situated in the first, and three in the second.

The upper series consists of the representative of the *os scaphoides* of the human subject (*fig.* 498. *w*); of the *os lunare* (*x*); of the *cuneiforme* (*y*); and of the *os pisiforme* (*z*).

In the lower series, the *os trapezium*, which supports the thumb of the human hand, does not exist in the horse; but the *trapezoid* (not seen in the figure); the *os magnum* (2.); and the *unciforme* (3.) are all of them readily identified.

Fig. 498.



Osteology of the Horse — Bones of the anterior Extremity.

Scapula.— *h*, its neck; *i*, spine; *k*, coracoid apophysis; *l*, *l*, inferior costa; *m*, *m*, superior costa; *n*, *n*, base; *o*, fossa subspinalis; *p*, fossa supra-spinalis.

Os humeri. — *a*, shaft of the bone; *b*, protuberance into which the teres major is inserted; *e*, bicipital protuberance; *f*, neck of the humerus; *i*, external condyle; *K*, double articular suface, articulated with the radius; *k*, internal condyle; *l*, anterior fossa which receives the upper head of the radius, when the fore-arm is bent; *m*, posterior sinus, for the reception of the olecranon of the ulna, when the fore-arm is extended.

Radius. — *n*, its upper head; *o*, protuberance for the insertion of the tendon of the biceps; *r*, its lower extremity.

Ulna.— *s*, the olecranon process; *t*, its articulation with the humerus; *u*, continuation of the bone which in aged horses becomes united with the radius.

Bones of the carpus.— *w*, Scaphoides; *x*, Lunare; *y*, Cuneiforme; *z*, Pisiforme or Orbiculare; 2, Os magnum; 3, Unciforme.

Metacarpus.— 4, 5. The great metacarpal or cannon bone. 6, 7. Rudimentary external metacarpal bone. 10, 11. Sesamoid bones.

Fore-foot. 12, 13. Proximal phalanx or great pastern bone. 14, 15. Middle phalanx or lesser pastern or coronary bone. 16. Terminal phalanx or coffin-bone. 17. Sesamoid bone.

The *metacarpal bones* are in the horse consolidated into one large piece, called by farriers the shank or cannon bone, and two smaller supplementary pieces, which seem merely appendages to the former.

The large cannon bone (*fig.* 498. 4, 5.) is formed by the union of two metacarpal bones indissolubly conjoined, — viz. of those which support the ring and middle fingers in the human hand; these conjoined, here form a massive piece, the upper end of which articulates with the carpus, while its distal extremity sustains the first joint of the foot.

A second or supplemental piece (*fig.*498.6,7.) is simply a rudiment representing the internal metacarpal bone of the human skeleton, or that which in man supports the little finger; superiorly this piece presents an articulating surface, which articulates with the unciform bone of the carpus, but inferiorly, there being no finger for it to support, it gradually dwindles away to a mere splint, which is applied against the ulnar aspect of the preceding bone.

The third bone of the metacarpus is equally rudimentary as the last, and consists of a similar styliform bone applied against the opposite side of the shank bone, and obviously representing the metacarpal bone of the fore finger.

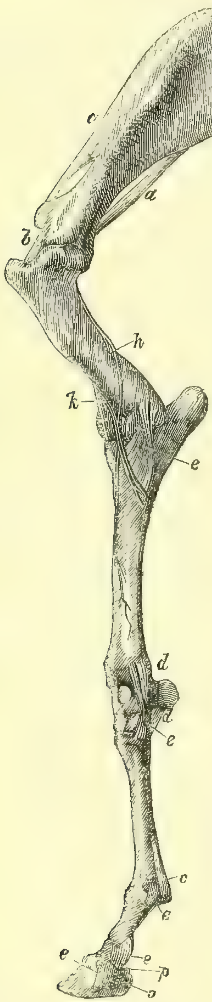
The fore foot of the horse is composed of three bones, representing the first, second, and third *phalanges* in the fingers of the human hand; but extraordinarily changed in their appearance. Of these, the first (*fig.* 498. 12, 13) is equivalent to the bones of the first phalanges of the ring and middle fingers in the human subject, as is indicated by a central groove, showing this piece to be composed of two lateral halves — this bone in the horse is called the "*great pastern.*"

The second piece (*fig.* 498. 14, 15.) corresponding with the second phalanx, is named, in common language the "*little pastern,*" while the third (16), the representative of the third phalanx, a bone of very large size and crescentic shape, has received from farriers the name of the "*coffin bone.*"

In addition to the above may be noticed two *sesamoid bones* (10, 11) implanted in the flexor tendon of the foot, as it passes behind the articulation between the cannon bone and the great pastern, and a third lying over the posterior part of the articulation, between the coffin bone with the coronary bone, or between the two distal phalanges.

Posterior extremity. — The *pelvis* of the solipeds, both in its disposition and in the shape of the bones composing it, differs in many important particulars from that of man, and even of the generality of quadrupeds. The body of the ileum is elongated into a sort of neck, while its crest and spine, extending themselves outwards almost at a right angle with the body, give the whole bone a shape somewhat like that of the letter T, or of a hammer, of which the body of the bone will form the handle, while the extremity of one of its branches is articulated to the side of the sacrum, and the other forms a broad expansion, the inner surface of which is turned obliquely towards the spinal column. The body of the ileum joins the ischium and pubis at a very obtuse angle, the cotyloid cavity being excavated in the usual manner in the line of junction between the three bones.

Fig. 499.

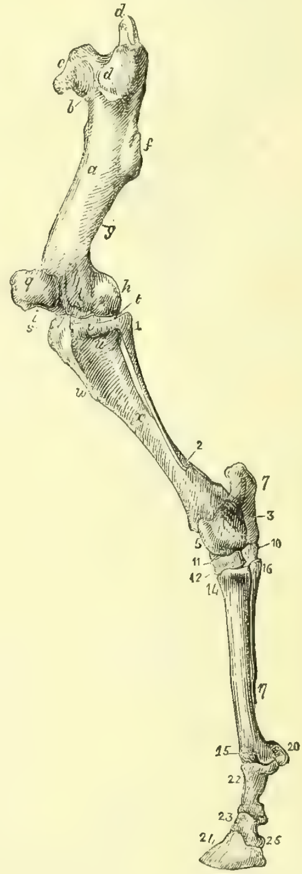


Ligaments of the anterior extremity of the Horse.

a, a, Ligaments of the scapula; *b,* capsular ligament of the shoulder-joint; *h,* radial nerve; *k,* capsule of elbow-joint; *d, d, d, e, e, e,* ligaments of the elbow, carpus, and phalanges; *o,* outer cartilage of the hoof; *p,* inner cartilage of the hoof.

The *os femoris* in the Solipeda is very strong and massive, with well developed trochanters, and prominent ridges for the attachment of the muscles implanted into it: it is however so short as to be entirely concealed within the flesh and integuments of the trunk, so that what is ordinarily designated the thigh in these quadrupeds is in reality the muscular portion of the leg. Inferiorly the articulating surface that sustains the patella is no longer, as in the human subject, continuous with that of the knee-joint, but forms a distinct articulation upon which the patella (*fig.*500. *q*) plays during the movements of the leg.

Fig. 500.



Osteology of the Horse.— Bones of the posterior Extremity.

Femur.— a, Body of the bone; *b,* its neck; *c,* the head incrusted with cartilage; *d, d,* trochanter major, or "spoke"; *f,* projection of the linea aspera, into which the glutæus externus is inserted; *g,* fossa, whence arises the gastrocnemius externus and plantaris; *h,* the external condyle; *i,* cartilaginous surface supporting — *q,* the patella.

s, t, external and internal semilunar cartilages of the knee-joint.

Tibia.— u, its upper head; *v,* articular surface, entering into the composition of the knee-joint; *w,* surface for the insertion of the ligamentum patellæ; *x,* shaft of the bone.

Fibula. — 1, Its upper extremity; 2, its lower end gradually diminished to a point.

Tarsus.— 3, 5, Astragalus or cockal bones; 7, os Calcis; 10, os Cuboides; 11, os Naviculare; 12, os Cuneiforme.

Metatarsus.— 14, Upper extremity, and 15, lower extremity of the great metatarsal or cannon bone. 16, 17, rudimentary external metatarsal bone; 20, Sesamoid bone.

Hind-foot.—22. Proximal phalanx, or great pastern; 23. Middle phalanx, or lesser pastern, or coronary bone; 24, Last phalanx or coffin bone; 25, Sesamoid bone.

The *leg* is in the Solipeda almost exclusively formed by the *tibia*, which is of great strength, and very massive towards its upper extremity, where the ridges for muscular attachment stand out in bold relief; inferiorly it becomes more slender, and approaches nearer to a cylindrical shape, expanding again inferiorly to form the articulating surface for the ankle joint.

The *fibula* (*fig.* 500. 1, 2.) is even more rudimentary in its development than the ulna in the anterior extremity, being, in fact, nothing more than a long spiculum of bone implanted among the muscles, and laid like a slender splint along the outer and posterior angle of the tibia, with which it is firmly connected by ligamentous attachments in the vicinity of the knee-joint, whence it descends separated by a small interval from the tibia as far as the middle of that bone, to which at this point it becomes closely applied, and then, gradually becoming more and more attenuated, is towards the lower third of the leg completely lost.

The bones of the *tarsus* in the horse are, 1st, the astragalus, or "cockal-bone," as it is vulgarly named (*fig.* 500. 3, 5.), the os calcis, or "heel-bone" (7), the cuboid (10), the navicular (11), the middle cuneiform and the lesser cuneiform (12). The internal or great cuneiform bone is here wanting, as also are the bones of the great toe, which, when present, it is destined to support.

The bones of the *metatarsus*, like those of the metacarpus, are three in number,—viz. one large central or cannon bone, and two lateral rudimentary pieces. The central piece (*fig.* 500. 14, 15.), which supports the entire weight of the body, is apparently composed of the conjoined metatarsal bones belonging to the second and third smaller toes; in the human skeleton the line of demarcation between the two being indicated by a deep longitudinal groove: by its upper extremity this bone articulates with the three lower bones of the tarsus; while inferiorly it presents a smooth articular surface, whereby it supports the first phalanx of the foot. The external rudiment (*fig.* 500. 16, 17.) is an imperfect metatarsal bone, occupying the place of that which in the human subject supports the little toe: by its upper extremity it articulates with the cuboid bone of the tarsus, while inferiorly, owing to the deficiency of the corresponding toe, it forms no articulation. The internal rudiment represents the metatarsal bone of the first of the small toes in the human foot: superiorly it articulates with the lesser cuneiform bone of the tarsus (12), whence, as it descends, it gradually diminishes in size, and is lost before it reaches the foot.

The bones of the hind foot resemble those already described in the anterior extremity, and are distinguished by similar names, the first *phalanx* of the solitary toe being the great pastern, the second the little pastern or coronary bone, and the third, or that which supports the hoof, the coffin bone: there are likewise the *sesamoid bones* (20), behind the articulation, between the cannon bone and the first phalanx, and also between the coronary and coffin bones (25).

Myology. — The myology of quadrupeds is, in many points of view, a subject of particular interest, more especially in those races which are far removed from man in their general habits or in the configuration of their skeleton. In the case of the Solipeds, owing to the exceedingly aberrant structure of their extremities, the disposition of their muscular system becomes a very important subject of inquiry, and it is partly from this cause, and partly from the necessity of obtaining an accurate knowledge of the anatomy of animals so valuable to mankind, that the myology of the horse and its congeners has been studied with great care, and delineated with extraordinary zeal and perseverance. It is for these reasons that we shall in the present article describe at some length this portion of their economy, premising that the details here given will be found more or less applicable to quadrupeds generally, except where obvious peculiarities of structure belong to the class which forms the more immediate subject of our study.

Panniculus carnosus. — On removing the skin, the entire body is in most quadrupeds found to be invested with a muscular covering, the thickness and consequent importance of which varies in different parts. In the human subject the traces of this fleshy pannicle are very feeble, being confined to certain regions,—such as the anterior part of the neck, the palms of the hands, &c.; but in the horse it forms a much more important investment, giving mobility to the integument, and materially contributing to the support and defence of various organs. This fleshy covering is very thick in the anterior region of the neck, whence it extends downwards upon the anterior extremities, and, becoming tendinous, is extensively inserted in conjunction with the tendons of the latissimus dorsi and teres major, into the external surface of the humerus. From this point strong muscular fibres pass downwards over the muscles of the fore-arm, where they terminate in a broad fascial expansion which embraces the lower part of the fore-leg. Another strong portion of this fleshy tegument spreads over the sides and loins, where it degenerates into a tendino-membranous layer, extending downwards as far as the penis, which it likewise invests with a carneo-membranous sheath. It likewise encases the buttocks and thighs in a strong covering of fleshy and tendinous fibres, which spreads downwards over the fascia lata to the hind leg.

In describing the other parts of the muscular system, it will be necessary to divide them into their appropriate regions, and in so doing, we shall follow the arrangement usually adopted in describing the human subject, beginning with the

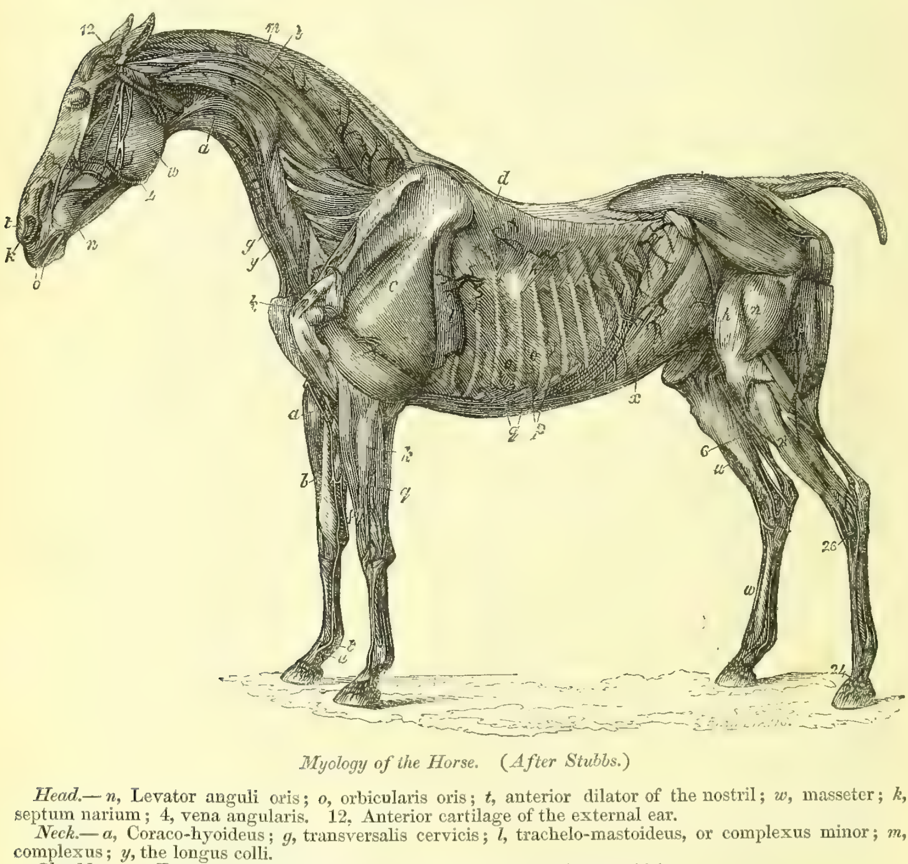
Proper muscles of the spine. — The long muscles of the spine, — viz. the spinalis and semi-spinalis dorsi, longissimus dorsi and sacro-lumbalis — present a disposition very similar to what occurs in the human subject.

The *spinalis dorsi* takes its origin from the spinous processes of the lumbar and posterior dorsal vertebræ, as well as from the broad fascia of the loins, and running forwards is inserted by distinct tendons into the spines of the anterior vertebræ of the back. Its continuation, the *spinalis cervicis*, is in the horse of great strength and importance: its origin commences from the second spine of the back, which origin is continued for about one third of the way down that spine towards its root: it arises likewise from the third dorsal spine and the ligamentum nuchæ; from these origins it runs forward to be implanted by strong and distinct tendons into the spines of the anterior cervical vertebræ.

The *longissimus dorsi* is situated immediately external to the spinalis, taking its origin from the common mass of muscle that arises beneath the lumbar fascia, as well as from the spinous processes of the loins and sacrum, whence it runs forward to be inserted by a double set of tendons into the transverse processes of the loins and back, and also into the posterior ribs near their angles. Its continuation, the *transversalis colli*, is likewise of considerable strength, but offers nothing worthy of remark.

The *sacro-lumbalis* arises, in conjunction with the latissimus dorsi, from the back of the sacrum, and also by flat tendons about

Fig. 501.



Myology of the Horse. (*After Stubbs.*)

Head.— *n*, Levator anguli oris; *o*, orbicularis oris; *t*, anterior dilator of the nostril; *w*, masseter; *k*, septum narium; 4, vena angularis. 12, Anterior cartilage of the external ear.

Neck.— *a*, Coraco-hyoideus; *g*, transversalis cervicis; *l*, trachelo-mastoideus, or complexus minor; *m*, complexus; *y*, the longus colli.

Shoulder.— *c*, Triceps extensor cubiti; *k*, tendon of the biceps flexor cubiti.

Forearm and anterior extremity.— *a*, *b*, *c*, Extensor carpi radialis; *k*, extensor digitorum communis; *q*, analogue of the extensor minimi digiti; 6, 9, ligaments; *t*, vena plantaris interna; *u*, nervus plantaris internus.

Trunk.— *d*, serratus minor posticus; *h*, serratus major posticus; *l*, serratus major anticus; *o*, external intercostals; *p*, internal intercostals; *q*, rectus abdominis; *x*, obliquus internus.

Hinder extremity.— *b*, glutæus medius; *h*, rectus femoris; *n*, vastus externus; *u*, *w*, 21, 26, 24, extensor digitorum pedis; 6. plantaris and gastrocnemius.

half the breadth of the muscle from the superior edge of all the ribs, except two or three of the most anterior; and its slips are inse ted by as many distinct tendons into the inferior edge of all the ribs, except two or three of the hindmost, and also into the transverse process of the seventh vertebra of the neck. The continuation of this muscle, the *cervicalis descendens*, offers nothing remarkable.

The *multifidus spinæ*, in the dorsal region arises by numerous tendinous origins from the transverse processes of the vertebræ of the back, loins, and sacrum, near their posterior protuberances, each slip running forwards to be inserted into the spinous process of the vertebra in front of that from which it derives its origin, the whole forming a thick mass, which fills up the hollow situated between the spinous and transverse processes. In the neck a similar disposition exists.

The *intertransversarii colli* take their origins from the roots of the oblique processes of the cervical vertebræ, and from between these and the transverse processes: in the horse they are of great strength and importance, running forwards to be inserted into the transverse processes of the vertebra in front of that from which they arise. In addition to the above there is a set of muscles named by Stubbs the *intervertebrales*, which do not exist in the human subject: these arise from the ascending oblique processes of the five inferior vertebræ of the neck, and from the space betwixt the oblique processes of the uppermost vertebræ of the back: they are each of them inserted into the lateral parts of the bodies of the vertebræ above their origin.

The *longus colli* is the only muscle, exclusively appropriated to the movements of the spine, situated in front of the spinal column. This muscle, in the horse, arises from the transverse processes of the third, fourth, fifth, and sixth vertebræ of the neck, from which origins it runs upwards to be inserted by distinct tendons into the anterior part of the bodies and transverse processes of the vertebræ above them, and into the anterior surface of the atlas.

The *quadratus lumborum* offers the same disposition as in the human subject.

The tail in quadrupeds, from its great development, requires for its movements a special set of muscles, of which scarcely any traces exist in the human subject. This organ in the horse is susceptible of three kinds of movements. It can be straightened or elevated, bent or brought downwards, and lastly carried to either side. These movements, again, by their combinations, produce secondary effects, so that the tail becomes susceptible of very extensive motions; and, in such quadrupeds as have this part very largely developed, it even supplies the place of a hand, so completely is it under muscular control.

In order to effect these different movements, three * distinct sets of muscles are employed, which are arranged upon the same plan as the long muscles in other parts of the spinal column; that is to say, they arise by numerous tendinous slips, and are inserted in a similar manner, the slips of origin and insertion running, of course, in opposite directions: the latter, moreover, are prolonged to a much greater extent than in the rest of the spinal column, and firmly bound down to the vertebræ by tendinous sheaths, so as to add as little as possible to the bulk of the tail.

The *muscles which raise or straighten the tail* are all situated upon its upper aspect: they are, first,

The *sacro-coccygeus superior* (*lombo-sus-caudien*). This muscle arises in the horse from the inferior or posterior edge of the third spinal process of the os sacrum, and from the spines, edges, and interspinal ligaments of the sacral vertebræ behind that point, as well as from those caudal vertebræ that are possessed of spinous apophyses. The fleshy mass formed from these origins gives off numerous slender tendons: the first of these is the shortest, and runs inwards to be inserted into the base of the first caudal vertebra, in which the articular apophyses are wanting. The second tendon is inserted in a similar manner into the succeeding vertebral piece; the third into the next, and so on to the end of the tail. The number of the tendons given off is, of course, determined by that of the vertebræ. Each tendon is lodged in a sort of ligamentous canal, which forms a sheath for it throughout its whole course. When these two muscles act in concert the tail is necessarily raised upwards.

The *interspinales superiores* (*spinalis obliquus; lombo-sacro-coccygien* of Vicq d'Azyr). These muscles are a continuation of the interspinous muscles of the spine; but as the spinous processes of the tail are short, and frequently replaced by two tubercles answering to rudiments of the oblique processes, these muscles are here disposed obliquely, being more widely separated posteriorly than they are in front.

The *muscles which depress the tail* or bend it downwards all take their origin in the interior of the pelvis, and are prolonged to a greater or less extent along the inferior aspect of the tail. These form, when completely developed, four pairs, or four pairs of series, of muscles.

1. The *ileo-coccygei* (*ileo-sous-caudien* of Vicq d'Azyr) arise from the internal or pelvic surface of the ossa ilei, and, forming an elongated fleshy belly in the interior of the pelvis, terminate beneath the root of the tail, which they will consequently depress with considerable force against the anus.

2. The *sacro-coccygeus inferior* (*sacro-sous-caudien*) is the antagonist of the sacro-coccygeus superior, above described, which in structure it exactly resembles. This muscle takes its origin from the inferior surface of the sacrum and of the transverse processes of those caudal vertebræ in which these processes are developed, by a fleshy belly which gradually diminishes in thickness, and termi-

* Cuvier, Anat. Comp. tom. i. p. 275.

nates by forming as many tendons as there are caudal vertebræ without transverse processes. These tendons are received into sheaths resembling those upon the upper surface of the tail, and are inserted successively into the base of each caudal vertebra, beginning about the seventh.

3. The *interspinales inferiores* (*sub-caudales, inter-coccygeus* of Vicq d'Azyr). These are situated beneath the mesian line of the tail. They commence underneath the articulation between the first and second caudal vertebræ, and form an elongated fleshy belly, which, in some quadrupeds that have the tail largely developed, become first of all implanted into V-shaped bones derived from the fourth, fifth and sixth vertebræ of the tail: they receive, moreover, from time to time additional fleshy slips, which go on continually diminishing in size, and give off tendons to be inserted successively into the inferior aspect of the base of each caudal vertebra.

4. The *pubo-coccygeus* (*pubo-sous-caudien*). This is a thin muscle, derived from the whole extent of the upper margin of the pelvis, and having the appearance of a fleshy membrane. the fibres of which are gradually collected into one point to be inserted beneath the tail into tubercles situated upon the base of the fourth and fifth vertebræ. The action of this muscle will produce an effect similar to that of the ileo-coccygeus.

The *muscles adapted to move the tail laterally* are arranged in two sets.

1. The *ischio coccygeus externus* (*ischio-caudien*) arises from the posterior or internal surface of the ischium, a little below and behind the cotyloid cavity, from which origin it runs backwards to be inserted into the transverse processes of the anterior caudal vertebræ. This muscle is improperly called by Stubbs the *levator ani*, because in the horse a few fibres of it are connected with the termination of the rectum.

2. The *intertransversales* (*intertransversal* of Vicq d'Azyr) extend in the form of musculo-aponeurotic layers over all the transverse processes that are developed in the caudal region, their tendons of insertion being most distinctly seen upon the upper surface of the tail.

In animals that have the muscular apparatus of the tail completely developed the muscles are found to consist of eight distinct sets, —viz., two superior, two lateral, and two inferior. In the horse some of these are deficient, or exist only in a rudimentary condition. To see them in their full state of development they must be examined in animals provided with long and mobile tails, such as the prehensile-tailed monkeys, the opossums, the lion, and, more especially, in the kangaroo and beaver.

Muscles derived from the spinal column which serve immediately for the movements of the cranium. — These have nearly the same origins as in the human subject, but are comparatively of much greater strength, owing to the inclined position of the head with respect to the vertebral column. They may be divided into such as proceed, 1st, from the atlas; 2nd, from the axis; and, 3rd, from the posterior cervical vertebræ and ligamentum nuchæ. To the first set belong —

1. The *rectus capitis posticus minor*, or rather *medius*, arising, as in the human subject, from the atlas; from this origin it runs to be inserted by a short and broad tendon into the occiput.

The other muscles belonging to the atlas — namely, the *rectus anticus*, the *rectus lateralis*, and the *obliquus superior* — offer the same position as in the man.

The muscles derived from the axis — viz. the *rectus posticus major* and the *obliquus inferior* — are likewise similarly disposed in all quadrupeds.

The muscles arising from the other cervical vertebræ are

The *complexus*, which, commencing from the upper oblique process of the third vertebra of the neck, continues its origin from all the oblique processes of the neck below that point, as well as from the upper oblique process of the first vertebra of the back, also by a pretty strong tendon from the transverse processes of the second and third dorsal vertebræ; from these origins it runs forwards to be inserted by a strong round tendon into the occiput close to its fellow of the opposite side: in this course it is connected by numerous tendinous processes with the ligamentum nuchæ. That portion of the complexus usually distinguished by the name of *digastricus colli* is in the horse undistinguishable as a distinct muscle.

The *trachelo-mastoideus*, or *complexus minor*, arises from the oblique processes of the third, fourth, fifth, sixth, and seventh cervical and first dorsal vertebræ, and from the transverse processes of the second and third vertebræ of the back; it runs forwards external to the last-mentioned muscles to be inserted by a strong tendon into the mastoid apophysis of the temporal bone. The above muscles are overlapped by the

Splenius capitis (*cervico-mastoiden*), which, arising by strong tendinous processes from the spinous processes of the two superior dorsal and two last cervical, and also extensively from the ligamentum nuchæ, runs forward to be inserted into the transverse processes of the fifth, fourth, and third cervical vertebra, and into the transverse ridge of the occipital bone. It is remarked by Cuvier that in carnivorous quadrupeds the splenius is not inserted into the transverse processes of the cervical vertebræ as it is in herbivorous animals and in the human subject, in which the latter portion is sometimes sufficiently distinct to obtain the name of *splenius colli* in contradistinction to the *splenius capitis*. It is likewise remarkable that in the camel, if the splenius exists at all, it is extremely thin and difficult to display by dissection.

Muscles of the ribs and sternum. — The muscles derived from and inserted into the ribs and sternum are found in all quadrupeds to have the same general arrangement as in the human subject. In the horse, their disposition is as follows, beginning with those whose office is to raise the framework of the chest and thus assist in inspiration.

The *scaleni* differ in no remarkable respect from the corresponding muscles in the human body. The same may be said of the *intercostal muscles*, the *levatores costarum*, the *serratus posticus superior* (*dorso-costien*), the *serratus posticus inferior* (*lombo-costien*), and the *triangularis sterni* (*sterno-costien*), the two latter of which must be regarded as depressors of the ribs, and consequently acting the part of muscles of expiration.

In all quadrupeds possessing a greater number of ribs, and consequently a more capacious thorax than man, the attachments of the *diaphragm* are found to be much further removed from the margins of the false ribs than in the human subject: nevertheless the position which it occupies, and its connections in the thoracic cavity, are similar in all mammiferous animals.

The *walls of the abdomen*, in the horse as in the generality of quadrupeds, are composed of five pairs of muscles, to which the same names are applicable as are bestowed upon them by the anthropotomist.

The *obliquus externus abdominis* (*costo-abdominien*) arises, by tendinous processes that indigitate with the origins of the serratus magnus, from the external surface of all the lower ribs, beginning at the fifth; and below the last rib it derives its posterior attachment from the fascia lumborum; from these origins, it runs backwards and downwards, terminating in a broad tendinous expansion, the terminations of which in the linea alba, os pubis, and Poupart's ligament, together with the formation of the external abdominal ring, are exactly as in the human subject.

The *obliquus internus* (*ileo-abdominien*) exhibits the usual arrangement, arising tendinous and fleshy from the crest of the ileum and pubic ligament, whence it mounts obliquely forwards to be inserted into the cartilages of all the lower ribs as far forwards as the ensiform cartilage of the sternum.

The *rectus abdominis* (*sterno-pubien*) is much more extensively developed in the horse than in human beings. Arising from the os pubis it passes forwards enclosed in its usual sheath to be inserted into the ensiform cartilage and into the cartilaginous terminations of the third, fourth, fifth, sixth, seventh, eighth and ninth ribs, and also into the sternum between the cartilages of the third and fourth ribs. There are even fleshy fibres derived from this muscle prolonged as far forwards as the articulation between the first rib and the sternum, which, by the old anatomists, was regarded as a distinct muscle, and named "musculus in summo thorace situs."

In many of the Carnivora the rectus abdominis is equally remarkable for its great length, and in some species it is even prolonged forwards to the very anterior extremity of the sternum. When the recti are thus largely developed the *pyramidales* do not exist.

Anterior extremity. Muscles of the shoulder. — It may readily be supposed that in the horse and other herbivorous quadrupeds not possessed of a clavicle, and, moreover, remarkable for the extreme simplicity of the structure of their scapular apparatus, these muscles undergo important modifications in their disposition and attachments, which it will be interesting to investigate. In the human subject the muscles specially appropriated to the movements of the shoulder are eight in number, — viz. the *serratus magnus*, the *pectoralis minor*, the *levator scapulæ*, the *rhomboideus*, the *trapezius*, the *omo-hyoideus*, the *subclavius*, and the *sterno-cleido mastoideus*, all of which concur in producing the various movements of which the human shoulder is susceptible. Of these, it will be observed, the six first belong exclusively to the Scapula, except the *trapezius*, which is inserted extensively into the clavicle; whilst the operation of the two last is upon the clavicle only.

In quadrupeds the shoulder is furnished with the same muscles as those which are met with in man, only they present differences in their proportions and attachments, which are dependent upon the structure of the skeleton, or the particular requirements of the animal; and, moreover, they are provided with an additional muscle, of which no vestiges appear in our own bodies. In the horse, the arrangement of the muscular apparatus of the shoulder is as follows.

The *trapezius*, in all quadrupeds destitute of clavicles, or in which these bones are but imperfectly developed, presents an arrangement very different from what exists in such as have the clavicles completely formed: that part which would in the latter case have been the clavicular portion, becomes confounded with the deltoid and with the cleido-mastoid (here a very distinct muscle from the sterno-mastoid). From the combination of these three, there usually results a single muscle, which is implanted immediately into the humerus, and which, from its attachments, might be named the *masto-humeralis*. It is this muscle which is named by Stubbs the *levator humeri proprius*, and its posterior part *musculus ad levatorem accessorius*; and by the French hippotomists *muscle commun de la tête de l'enclosure et du bras*. This clavicular portion of the trapezius is very distinct from the scapular portion, from which it is in many animals separated by the *trachelo-acromial* muscle, to be described further on.

In the horse, therefore, the Trapezius may be said to consist of that part only which is called the ascending portion in the human subject, and which is inserted into the posterior margin of the spine of the scapula. The *sterno-mastoid* is present, but the *levator anguli scapulæ*, the cleido-mastoid, and the clavicular portions of the *trapezius* and *deltoid* are all replaced by the muscular expansion above described, and which, taking its origin from the mastoid process of the temporal bone and from the transverse processes of some of the superior cervical vertebræ, passes downwards in front of the head of the humerus and descends along the inner surface of the forearm, into which it is ultimately inserted.

The muscle of the shoulder which is proper to quadrupeds may be named the *trachelo-acromialis* (*acromio-trachelien*, Cuv., *acromio-basilaire*, Vicq d'Azyr). It arises in the horse from the transverse process of the atlas and of the four following cervical vertebræ (in the generality of quadrupeds from the three uppermost only); from this origin it descends towards the shoulder-joint, making its appearance externally between the two divisions of the trapezius, which it separates; it then spreads out over the acromial portion of the scapula, and descends as far as the middle of the humerus, where it is inserted. Its action will, of course, be to draw the shoulder upwards and forwards. This muscle, which exists in all the mammalia, with the exception of the human species, would seem to be in special relation with the quadrupedal mode of progression; and, as Cuvier observes, affords a striking example of the difficulty of establishing a good nomenclature in comparative anatomy: in some animals, it derives its origin exclusively from the cranium; and, in others, from the upper or lower cervical vertebræ. Its mode of insertion is equally various; in the tapir it is implanted into the aponeurosis which covers the deltoid muscle; while, in the horse, it has its insertion into the middle portion of the humerus by two aponeurotic tendons, which embrace the brachialis internus muscle.

The *serratus major anticus* (*scapulo-costien*), in the horse, arises from the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and also from the external surfaces of the six superior ribs: its origins extending as far backwards as the insertion of the tendons of the sacro-lumbalis: from this extensive origin it passes backwards around the chest to be implanted into the base of the scapula, its insertion occupying nearly half of the internal surface of that bone. This muscle, Cuvier remarks, is much more extensively developed in quadrupeds than in the human subject; for, in all other mammalia, except in the orang-outang, it arises not only by digitations from the ribs, but also from the transverse processes of the vertebræ of the neck, an arrangement which becomes necessary in animals that walk upon four feet, in order to prevent the scapula from being pushed too far backwards towards the spine. This muscle, in fact, forms, with its fellow on the opposite side, a kind of sling, by which the trunk is suspended. The fact that it is equally extensive in its attachments in the Monkeys, is an additional proof that the usual mode of progression in these animals is on four feet: in these animals, indeed, the serratus magnus derives origins from all the cervical vertebræ, instead of from only a part, as in other mammifera. In the Cetaceæ that do not walk, and in the kangaroos which have their anterior limbs very small, the serratus magnus presents a corresponding feebleness of developement.

The *pectoralis minor* (*serratus minor anticus*) is, in the horse, represented by a muscle, which, arising from the sternum and from the first, second, third, and fourth ribs near their sternal terminations, runs upwards and backwards to be inserted into the superior costa of the scapula near the base of that bone; it also contracts tendinous attachments with the aponeurotic covering of the teres minor and other scapular muscles.

The *rhomboideus* arises, in the horse, entirely from the ligamentum nuchæ, and from the spines of the anterior dorsal vertebræ, whence it runs outwards to be affixed to the base of the scapula.

In monkeys and in the carnivorous quadrupeds the rhomboideus is continued upwards as far as the occiput, whence it derives an extensive origin; the occipital portion, indeed, is, in the Carnivora, separated from the rest so as to form a distinct muscle, called by some writers the *occipito-scapularis*, and, by Cuvier, "*rhomboïde de la tête*."

The *omo-hyoideus* is, generally, wanting in animals whose scapula presents no coracoid process: neither can there be any *subclavius* in animals that do not possess a clavicle: in the horse, however, the former of these is represented by a strong muscular fasciculus.

In this place it may be proper to notice the muscle named by the human anatomist *sterno-cleido-mastoideus*; but which, in the lower animals, is represented by two distinct muscles. One of these,

The *sterno-mastoideus*, or, as it might be named, sterno-maxillaris, arises, in the horse, from the anterior end of the sternum, and, running forwards strong and fleshy, is inserted by a flat tendon into the inferior maxilla underneath the parotid gland, sending, however, another tendon to be implanted into the root of the mastoid process.

The *cleido-mastoideus*, always a distinct muscle from the preceding, is, as we have seen above, in the horse and other non-claviculate quadrupeds, confounded with the clavicular portions of the trapezius and deltoid.

Muscles inserted into the humerus. — The movements of the humerus in the human body are effected by two sets of muscles: one derived from the trunk, the other from the framework of the shoulder. The former are the pectoralis major and latissimus dorsi; the latter, the supra-spinatus, the infra-spinatus, and the subscapularis proceeding from the surfaces of the scapula, and the deltoid, teres minor, teres major, and coraco-brachialis, which take their origins from the processes. In the horse and in other quadrupeds, various circumstances render modifications in the arrangement of these muscles indispensable.

The *pectoralis major* (*sterno-humerien*), in the horse, arises, first, from the aponeurosis of the external oblique muscle of the abdomen; secondly, from the two lower thirds of the sternum; and, thirdly, from the superior part of the sternum for about one-third of its length. The first of these portions winds round to be inserted into the internal aspect of the head of the humerus; the second ends in a fascia, which descends downwards over the fore-arm, while the third, running in a transverse direction over the inferior portion, is inserted into the humerus along with the "levator humeri proprius" between the biceps and the brachiæus internus.

In all those mammalia which are destitute of complete clavicles, even in the Cetacea, there is a part of the sternal portion of the pectoralis major, which is inserted perpendicularly into the humerus, that joins the corresponding portion of the opposite side to form the *muscle common to both arms*," by the action of which the two fore-legs are made to cross each other.

The *latissimus dorsi* (*lombo-humerien*), in the horse, and in other quadrupeds, exhibits the same arrangement as in the human subject: it is, however, in the lower animals powerfully assisted in its action by the massy muscle already described (*cutano-humerien*), formed by the panniculus carnosus, a strong tendon from which is inserted into the humerus along with that of the latissimus dorsi. Both are intimately connected with the tendon of the teres major, and from this combination of tendons arises one of the heads of the triceps extensor cubiti.

The *supra-spinatus*, the *infra-spinatus*, the *subscapularis*, the *teres major*, and the *teres minor* have, in all quadrupeds, the same arrangement as in the human subject, the only differences being dependent upon the shape and proportions of the scapula.

The *deltoid* in all animals having their clavicles imperfect or wanting, is necessarily modified in its disposition to a very considerable degree. We have already seen when speaking of the trapezius, that its clavicular portion is in such cases blended with the anterior division of that muscle: that part only which takes its origin from the scapula remains to be noticed. Where the acromion is well developed, the deltoid may be divided into two portions; one derived from the acromion, the other proceeding from the spine and subjacent surface of the scapula: these two portions unite, and, decussating each other, form a common tendon, which is implanted into the deltoid ridge of the humerus. As the acromion process diminishes in size, the acromial portion of the deltoid becomes enfeebled in like degree, until at length, as in the horse, where there is no acromial projection, that part of the deltoid arising from the spine remains alone. Under these circumstances, this muscle is directed forwards in nearly the same direction as the infra-spinatus, and, both from its position and office has been named by hippotomists the "*abductor longus brachii*."

The *coraco-brachialis* exists even in animals that have no coracoid process, in which case it takes its origin from a little tubercle situated upon the superior costa of the scapula. When the biceps arises by two heads, as in the human subject, the coraco-brachialis arises with the longer head by a common tendon; but when, as is the case in many quadrupeds, the biceps has but one origin from the humerus, the coraco-brachialis is in no way connected with that muscle.

Muscles of the forearm. — *Flexors.* — The *biceps*, in the generality of quadrupeds, has the same origins as in the human subject; one head arising from the neck of the scapula, the other from its coracoid process: these two heads uniting form a common tendon, which is inserted into the tubercle of the radius, and, by an aponeurotic expansion into the fascia covering the muscles of the forearm; but where the coracoid process of the scapula is deficient, as in the horse, and in the carnivora generally, the term "biceps" is no longer applicable to this muscle, seeing that it has but one origin from the margin of the glenoid cavity: in the rest of its course it is similarly disposed in all the mammalia.

The *brachiæus internus* (*humero-cubitien*) in all quadrupeds has the same arrangement as in the human subject. In the horse, the biceps and the brachiæus are by most writers named the "long and short flexors of the forearm."

Extensors. — The *triceps extensor cubiti* (*scapulo-olecranien*) is in the horse a muscle of prodigious strength, and consists of three portions similar to those named in the human anatomy the long extensor, the short extensor, and the brachialis externus (the great extensor, the middle extensor, and the short extensor of Bourgelat, and other writers on the anatomy of the horse). There is, moreover, a fourth portion, derived from the common tendon of the latissimus dorsi and teres major, by the intervention of which, it takes its origin from the inferior margin of the scapula.

The *anconæus* (*epicondylo cubitien*) exists in all quadrupeds.

As might be expected from the construction of the bones of the forearm, both the *pronator muscles* are in the Solipeda entirely wanting, as is the case in the Ruminantia and in the Pachydermata generally; nevertheless, in the elephant and in the hog-tribe the pronator teres is feebly developed; and, as the mobility of the bones of the forearm becomes more perfect, as in the Carnivora, Quadrumana and Marsupialia, both the pronators are found presenting the same arrangement as in the human body.

The *supinators* are quite obliterated in the Solipeda, as well as in the Ruminantia and Pachydermata.

Muscles of the carpus and metacarpus. — The muscles employed in bending the wrist are in our own persons the palmaris longus, the flexor carpi radialis longior, the flexor carpi radialis brevior, the extensor carpi radialis, the flexor carpi ulnaris, and the extensor carpi ulnaris; of these one only is inserted into the carpus, all the rest being attached to the metacarpal bones.

In all multi-digitate mammalia, such as the Quadrumana, Carnivora, Rodentia, and Edentata, these six muscles exist and are disposed pretty nearly as in the human race; but in the Pachydermata and Ruminantia there is but one flexor carpi radialis. In all the above multidigitate animals, the muscles derived from the external condyle, and its vicinity by their co-operation, approximate the back of the hand towards the forearm, or, in other words, are extensors of the fore-foot; while those derived from the internal condyle have a contrary effect, and act as flexors of the hand. Should the flexor and extensor of the same side of the limb act together, the hand will be bent laterally in the corresponding direction.

In the Solipeda, where the movements of the wrist are strictly limited to those of flexion and extension, the disposition of these muscles is considerably modified.

The *extensor carpi radialis* is here single, arising from the anterior part of the external condyle of the humerus, and from the external surface of that bone for a considerable distance: it forms a strong fleshy belly, terminating in a powerful tendon, which runs to be inserted into the base of the anterior surface of the metacarpal or cannon bone. This muscle, called by Bourgelat the "*extenseur droit anterieur du canon*," seems, from the extent of its origin, to represent the long supinator and the two radial extensors of the wrist combined, and all three made to cooperate in the extension of the wrist.

The *flexor carpi radialis* (*epitrochlo-metacarpien*) arises from the external condyle of the humerus, and is inserted into the posterior surface of the base of the cannon bone, forming the antagonist to the preceding muscle: this is the "*flechisseur interne du canon*" of Bourgelat.

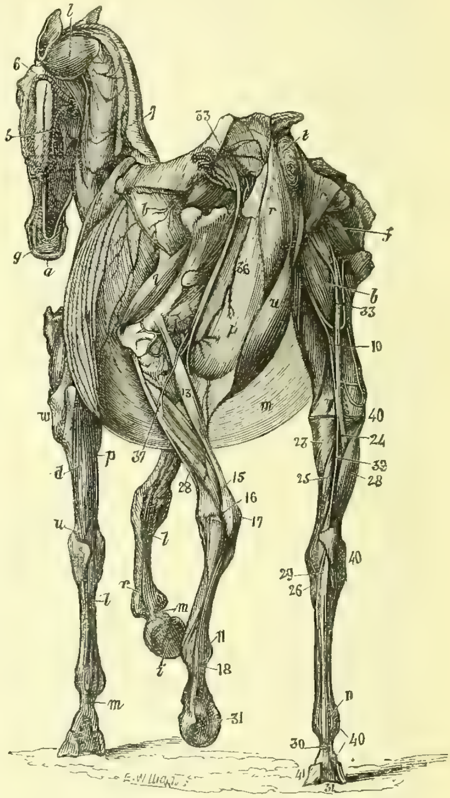
The *flexor carpi ulnaris* (*epitrochlo-carpien*) arises from the posterior part of the external protuberance of the os humeri, and also by a distinct head from the protuberance situated above the internal condyle; its tendon is inserted into the representative of the pisiform bone and also into the root of the rudimentary metacarpal bone beneath it: this is the "*flechisseur oblique du canon*" of Bourgelat.

The *extensor carpi ulnaris* (*cubito-sus-metacarpien*) arises from the posterior part of the external condyle of the humerus, and is inserted, like the preceding, into the os pisiforme, whence it is prolonged beneath the carpus, so as to perform the office of a flexor of the wrist ("*flechisseur externe*" Bourgelat.)

The *palmaris longus* does not exist in the Solipeda; nor is it found in the Pachydermata and Ruminantia, being in these orders of quadrupeds apparently combined with the flexor sublimis digitorum, as is likewise the case with this muscle in the bear, the badger, and the dog; in all other unguiculate quadrupeds it is disposed as in the human subject.

Muscles of the hand. — The *extensor communis digitorum* (*epicondylo-sus-phalangettien commun*). — This muscle in the horse is called by Bourgelat "*l'extenseur anterieur du pied*," and by Lafosse, "*l'extenseur du pied*:" it arises from the external condyle of the humerus and from the contiguous fasciæ, also from the upper and lateral part of the radius; its fleshy belly is strong, and terminates in a single tendon, which runs over the foot to be inserted into the last phalanx or coffin-bone, having previously given off a slip to join the tendon of the extensor minimi digiti.

Fig. 502.



Myology of the Horse. (*After Stubbs.*)

Head. — *a*, Orbicular muscle of the mouth; *g*, elevator of the chin; 5, arteria angularis; 6, arteria temporalis.

Neck. — *l*, Obliquus capitis inferior; 7, ligamentum nuchæ.

Trunk. — *m*, Transversalis abdominis; *t*, sphincter ani.

Left anterior Extremity. — *w*, Insertion of brachialis anticus; *d*, flexor profundus digiti; *p*, flexor carpi radialis; *u*, ligaments of the carpus; *l*, *m*, tendon of the flexor sublimis perforatus.

Right anterior Extremity. — *l*, *m*, Tendon of the flexor sublimis; *i*, insertion of flexor profundus into the coffin bone; *r*, flexor brevis digiti pedis.

Left posterior Extremity. — *p*, adductor magnus femoris; 7, vastus internus; *u*, gracilis; 13, 15, plantaris; 28, flexor longus digiti pedis; 16, external malleolus; 17, Internal malleolus; 18, division of the tendon of plantaris, to allow the tendon of the flexor profundus to proceed to its insertion at 31, into the coffin bone; 11, flexor brevis digiti pedis; 36, obturator artery; 37, nerves to the tibialis anticus.

Right posterior Extremity. — *c*, Tranversalis penis;

f, glutæus internus; *b*, iliacus internus; 10, vastus internus; 33, sciatic nerve; 23, poplitæus; 25, 26, tibialis posticus; 28, 29, 30, 31, flexor longus digiti pedis; 24, poplitæal nerve; 38, posterior tibial nerve; 40, articular ligaments of the knee ankle and pastern joints; 26, insertion of the tendon of the tibialis posticus into 29, that of the flexor longus digiti pedis; 11, flexor brevis digiti pedis; 31, insertion of the tendon of the flexor longus into the coffin bone; 41, internal cartilage of the hoof.

The *extensor proprius minimi digiti.* — In the horse this muscle is represented by two muscles. One of these, called by Bourgelat the *lateral extensor of the foot*, and by Lafosse *the extensor of the pastern*, is inserted by the intervention of a strong tendon into the side of the first phalanx of the solitary toe that forms the foot. The second muscle, placed between the above and the preceding muscle, furnishes a similar tendon, which, after passing in front of the carpus, becomes united at an acute angle with that of the former, the two co-operating with each other in extending the foot.

In the Ruminantia likewise this muscle is disposed after two different manners. In the Cervidæ or deer tribe, in which the rudimentary toes are capable of distinct movements, it furnishes two tendons to the two outer toes; whilst in oxen, goats, sheep, and antelopes its tendon presents a double insertion — one into the posterior aspect of the outer finger, the other into the tendon of the extensor communis.

The *extensor proprius indicis* and the two long extensors of the thumb are, in all the ungulate quadrupeds, entirely wanting.

The *abductor longus pollicis* is present in all the mammalia, even in the Ruminantia and the Solipeds. In the horse its tendon is implanted into the internal surface of the base of the cannon bone, so that it thus becomes an extensor of the foot (*l'extenseur oblique du canon* of Bourgelat).

The *flexor digitorum sublimis perforatus* and the *flexor profundus perforans.* — In the horse these muscles arise in common from the internal protuberance of the os humeri, and the two are confounded together for a considerable distance, when the two muscles separate to form two distinct tendons; of these, that belonging to the flexor sublimis runs beneath the annular ligaments of the carpus, to be inserted into the base of the great pastern bone previously dividing to give passage to the tendon of the profundus on its way to be implanted into the last phalanx or coffin bone of the foot.

In the ungulata the *small muscles of the hand* would evidently be useless, and accordingly in the horse all traces of them are lost, their place being supplied by the peculiar structure of the foot, to be described further on.

Posterior Extremity — Muscles of the Pelvis. —The muscles specially belonging to the pelvis are the *quadratus lumborum* and the *psoas parvus*, which in quadrupeds offer precisely the same arrangement as in man.

Muscles inserted into the os femoris —These are similarly disposed in all the Mammifera possessed of a pelvic extremity, the only differences observable being in their proportionate sizes. In the Solipeda the analogue of the *glutæus maximus* is so small, in comparison of the two other glutæi, that it is named by Bourgelat "*le petit fessier*," and by Stubbs the *glutæus externus.* In the human subject the comparative large size of this muscle is rendered necessary in consequence of the erect attitude of the body, which it principally assists in maintaining; whilst in quadrupeds, from the horizontal position of their bodies, it becomes of very secondary importance. In the horse it is a comparatively slender muscle, deriving its principal origin from the sacral fascia, but also reinforced by a long slender fasciculus, which descends immediately from the upper portion of the ileum. Its insertion is into the third trochanter and external rough surface at the upper part of the thigh bone, and also by strong tendinous aponeuroses into the fascia lata.

The *Glutæus medius* is the principal muscle in this region; it arises extensively from the sacro-iliac aponeurosis, and from the external surface of the ileum, from which origin it runs downwards and forwards to be implanted into the outer surface of the great trochanter, and is, moreover, prolonged, by means of a strong posterior fasciculus, towards the lower extremity of the femur. From this latter circumstance, as well as from its preponderating strength, the glutæus medius may be regarded as being, *par excellence*, the kicking muscle in these quadrupeds which instinctively have recourse to this mode of defence as best suited to their organization.

The other muscles inserted into the great trochanter — namely, the *glutæus minimus*, the *quadratus femoris*, the *obturator externus*, the *obturator internus*, the *gemelli*, and the *pyramidalis* —present in all quadrupeds a disposition similar to that which they have in the human body.

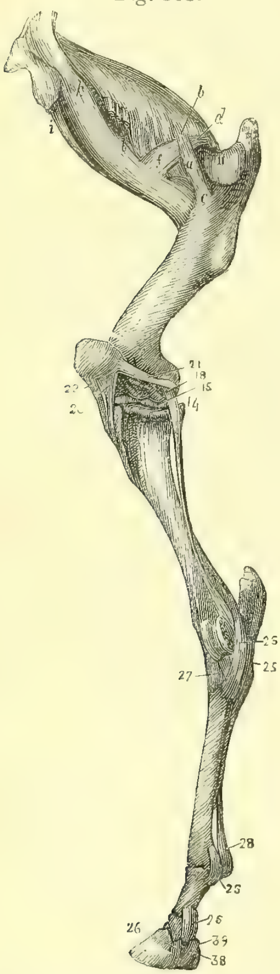
The muscles passing between the pelvis and the lesser trochanter, and also those that arise from the pubis to be implanted into the internal surface of the thigh, in the generality of quadrupeds, correspond very accurately with those of man. In the horse these are the *psoas magnus*, the *iliacus*, the *pectinæus*, and the *triple adductor*, none of which offer any peculiarity worthy of remark.

The *flexor muscles of the leg* are the *biceps flexor cruris*, the *semimembranosus*, the *semitendinosus*, the *sartorius*, the *gracilis*, and the *poplitæus*, all of which are enclosed by the dense fascia of the thigh, or fascia lata, which is kept tense by the action of a special muscle named the *tensor vaginæ femoris.*

The last-named muscle, called also the *musculus fasciæ latæ* (*ileo-fascien*) arises in the horse from the anterior portion of the crest of the ileum, whence it descends obliquely downwards, enclosed between two layers of the fascia, covering the thigh, into which it is strongly inserted.

The *extensor muscles of the thigh* — viz. the *biceps* (*ileo-rotulien*), the *vastus internus*, the *vastus externus*, and the *cruralis* — offer in all quadrupeds the same general disposition as in man, the three last forming one great common muscle (*trifemoro-rotulien*). The anterior margin of the thigh in the horse and in other quadrupeds is formed by the *sartorius* (*ileo-pretibien*), which here, from its position and office, has been named by hippotomists the "*long adductor of the thigh.*"

Fig. 503.



Deep muscles of the thigh and ligaments of the posterior extremity of the Horse.

a, b, c. A muscle named by Stubbs "*musculus parvus in articulatione femoris situs:* it arises by a flat tendon (*b*), from above the tendon of the *rectus cruris* (*d*), and is inserted tendinous into the os femoris (*c*); *i, k, l, iliacus internus.* The small numerals indicate the principal ligaments of the limb.

The *biceps* (*ischio-peronien*) in the horse and the greater number of quadrupeds, not even excepting the quadrumana, arises by a single origin, which is derived from the ischium, and the neighbouring ligaments and fascial expansions. This muscle covers a large proportion of the outer surface of the thigh: its principal insertion is into the head of the fibula, but it likewise throughout its whole length contracts extensive and important attachments with the fascia lata, so that it also becomes a powerful extensor of the thigh. There is moreover, in the horse and in the Ruminantia, a distinct portion of the biceps derived from the sacro-sciatic aponeurosis, the fibres of which are directed obliquely from before backwards, which, meeting the ischiatic portion at an angle, form with it a kind of raphe, which is prolonged for some distance. This muscle is called by Bourgelat the "*vastus longus*" of the thigh.

The *gracilis* (*pubio-pretibien*) is in all quadrupeds a very considerable muscle, more especially in such as have the thigh much shortened, as is the case in the horse, and the ungulata generally. It is called by Bourgelat the "*short adductor of the thigh,*" whilst he gives the name "*gracilis*" to the semitendinosus.

The *semimembranosus* (*ischio-sous-tibien*) and the *semitendinosus* (*ischio-pretibien*) have in all quadrupeds the same origin and general arrangement as in man; but both of them are in the lower animals inserted into the tibia by a broad aponeurosis. It must also be remarked that their insertion extends much lower down than in the human subject, a circumstance which causes the leg to be permanently kept in a semiflexed condition; and is one of the great obstacles to their walking in an upright position. Even in the Quadrumana these muscles have their insertions very low down in the leg.

The *poplitæus* has nothing remarkable in its disposition.

Muscles implanted into the foot. The *gastrocnemii* (*bi-femoro-calcanien*) and the *solæus* (*tibio-calcanien*) are less considerable muscles, as regards their comparative size in quadrupeds, than in the human race: nevertheless their general disposition is invariably the same as in man. In the *Solipeda*, the *solæus* is remarkably slender and feeble.

The *plantaris* (*femori-calcanien*). — In the Solipeds this muscle is remarkably developed, so much so indeed as apparently to represent the flexor sublimis. In the horse this muscle arises under the external head of the gemellus from a large fossa in the os femoris above the external condyle: its tendon is continued downwards, and runs over the extremity of the os calcis, where it is enclosed in a sheath formed by strong ligaments, which prevent it from slipping out of its place; passing on from this point, it divides, to be inserted upon each side of the posterior surface of the great pastern bone towards its inferior extremity, here giving passage between its two insertions to the tendon of the long flexor of the toe, which it serves to bend down closely to the pastern when the fetlock joint is bent, thus seeming to perform the functions both of the *plantaris* and of the short flexor of the toes.

The *tibialis anticus.* — In the Ruminantia and in the Solipeds, the *tibialis anticus* is in-planted into the anterior surface of the base of the metatarsal or cannon bone, so as to be simply an extensor of that portion of the foot which in these animals is usually misnamed the leg.

The *tibialis posticus* is altogether wanting in the Solipeds, as also in the Ruminantia and the hog-tribe.

The three *peronei* are, in the horse, represented by a single muscle, the tendon of which becomes conjoined with that of the long extensor of the digit, with which, when in action, it co-operates.

Muscles inserted into the digit. — The abductors and adductors* are the *abductor pollicis*, the *adductor obliquus pollicis*, the *adductor transversalis*, the *abductor minimi digiti*, and the *interossei*.

The *flexor muscles* in the horse are necessarily reduced to a state of extreme simplicity ; the short flexor communis is entirely wanting ; the *plantaris*, as described above, considerably increased in importance, has a double insertion into the base of the great pastern bone, and presents a similar disposition to that of the flexor perforatus in digitate quadrupeds, while the *flexor communis longus perforans*, here reduced to a single tendon, appropriated to the solitary toe, passes on as usual to be inserted into the last phalanx.

The *flexor longus pollicis* exists both in the Ruminantia and Solipeda, notwithstanding the total absence of a thumb in these animals ; but, instead of its usual destination, it here becomes affixed to the tendon of the flexor communis perforans, to which it forms a powerful auxiliary.

The *extensor muscles* of the toes in all digitate quadrupeds, provided with a representation of the great toe in the human foot, resemble those of man : in other animals there are some peculiarities that require notice. In the Quadrumana, the three muscles found in the human foot are present ; but in addition to these there is a proper *abductor of the thumb* (*adductor*, as it would be called by the anthropotomist), situated upon the inner side of the extensor pollicis longus, of which no traces exist in mankind.

Where the inner toe is wanting, as in the dog and the rabbit, the extensor pollicis is likewise deficient.

In the cloven-footed quadrupeds there is a proper extensor to the inner toe representing that of the thumb, and the peroneus longus, which is inserted into the external toe, performs the office of extending that also : there is moreover in Ruminants a long abductor of the thumb, the tendon of which is inserted close to that of the tibialis anticus

In the Solipeds, the *extensor communis* (*peroneo-sus-onguien*) terminates in a single tendon, which is inserted into the dorsum of the last phalanx of the foot: it receives, however, in transitu, a few fleshy fibres derived from the cannon bone, which represent the *extensor brevis* of unguiculate quadrupeds.

In the Solipeda, as might be expected, the *abductors and adductors* of the toes are entirely wanting.

Muscles which act immediately upon the lower jaw. — These are the *masseter*, the *temporal*, and the two *pterygoidei*, which in all quadrupeds have the same general arrangement as in human beings.

Muscles of the os hyoides. — The os hyoides of the Solipeds is constructed in accordance with a plan common to the Ruminants, and many Pachydermatous quadrupeds. Its body is arched and broad, presenting in the middle of its fore part a simple tubercle, and a tolerably long apophysis. It is consolidated with the superior cornua, which together form a very open arch. The single piece forming the anterior cornu is articulated to a rounded tubercle, situated just in front of the union between the posterior cornua and the body of the os hyoides, so as to admit of a considerable degree of motion in this joint. At its termination it is connected to the styloid process, which is very long and slightly forked.

The movements of the os hyoides are effected by numerous muscles, derived from several sources, the general arrangement of which, in most quadrupeds, conforms pretty nearly with what occurs in the human species.

The *sterno-hyoideus* exists in all quadrupeds, or, at least, is represented by a muscle of correspondent effect, derived from the sternum. In the Solipeda and in Ruminants, the sterno-hyoideus and the sterno-thyroideus form but a single muscle, which divides, to be inserted into both the larynx and os hyoides.

The *omo-hyoideus* in the horse is a very strong muscle, resembling in its origin that of the human subject ; but in some ruminants, as, for example, in the sheep, the analogue of the omo-hyoideus is derived from the transverse processes of the inferior cervical vertebræ.

The *genio-hyoideus* and the *mylo-hyoideus* have nearly the same arrangement in all mamiferous quadrupeds.

In the horse, all three of the above muscles are present. The *stylo-hyoideus* furnishes a sheath to the longer portion of the digastricus, and extends from the furcate extremity of the styloid bone to the base of the posterior corner of the os hyoides : this is the "*grand cerato-hyoidien*" of Gerard. There is also a "*cera-toidien lateral*" (*cerato-hyoideus*) of Girard, extending between the corner of the os hyoides and that of the thyroid cartilage.

Thirdly, there is the *mastoido-styloideus* (*stylo-hyoidien* of Gerard), a short thick muscle, derived from the long pyriform apophysis of occipital bone, whence it descends towards the angle of the styloid bone, into

* In comparative anatomy, owing to the permanently prone condition of the hand and foot of animals, it is impossible to employ the terms abductor and adductor, external and internal, &c., in the same sense as the anthropotomist: by *abductors* we therefore mean muscles which separate the external from the middle fingers, by *adductors* those which bring the fingers more closely together.

which it is inserted, above the origin of the stylo-hyoideus.

The other muscles of this region exhibit no peculiarities worthy of notice.

The muscles of the tongue, of the palate, and of the larynx, are in most quadrupeds strictly comparable to those of the human species.

Muscles of the Face. — These, from the conformity of their general arrangement with what exists in man, are distinguishable by the same names as are employed in human anatomy.

Fig. 504.

Facial Muscles of the Horse. (*After Sir Charles Bell.*)

a, orbicularis palpebrarum; *b, d*, cutaneous slips which raise the outer and the inner commissures of the eyelids; *c*, depressor of the lower eyelid; *e*, zygomaticus; *f, g*, levator anguli oris alæque nasi; *h*, elevator of the upper lip; *i*, dilator narium; *k*, nasal cartilage; *l, m*, orbicularis oris; *n*, masseter.

The *epicranius*, or *occipito-frontalis*, exhibits the usual origin from the posterior part of the cranium, whence, running forwards, it covers the skull with its tendinous aponeurosis, and, in front, spreads in muscular slips upon the forehead, some of which (*fig.* 504. *l*) extend downwards, to spread over those of the orbicularis palpebrarum.

Situated upon the outer side of the orbit there is another descending slip of muscle (*fig.* 504. *d*), apparently derived from the lateral muscle of the cartilage of the ear which, by elevating the external canthus of the eye, contributes much to the expression of that organ.

The *orbicularis palpebrarum* (*fig.* 504. *a a*) arises, as in the human subject, from the commissural ligament at the inner canthus of the eyelids, whence it winds round the orbit, its lower fibres receiving attachment from the os lachrymale.

Internal to the last-named muscle are a few fibres, that represent the *corrugator supercilii.*

The *Levator anguli oris* (*fig.* 504. *f, g*) is, likewise, extensively inserted into the upper lip and margin of the nostril: it has two origins, derived from the surface of the superior maxillary bone, between which the lateral dilator of the nostril and upper lip passes to its destination.

The *depressor of the lower eyelid* (*fig.* 504. *c*) is a short muscular slip, the use of which is sufficiently indicated by its name.

The *zygomaticus* (*fig.* 504. *e*) is a depressor of the external angle of the eye, as well as an elevator of the corner of the mouth, its fibres being intermixed with those of the orbicularis palpebrarum, as well as of the orbicularis oris.

The *long dilator of the nostril, and elevator of the upper lip* (*fig.* 504. *i*), arises at a little distance below the inferior margin of the orbit; and, passing between the two origins of the levator anguli oris, terminates in a tendon, which becomes connected with that of the opposite side, and then spreads out in front of the upper lip.

From the tendon of the last muscle arises the *anterior dilator of the nostril* (*fig.* 504 *h*), which, acting upon the interior nasal cartilage, powerfully expands the aperture of the nose.

The other muscles — viz. the *orbicularis oris*, the *levator labii superioris*, the *elevator of the chin*, and the *depressors of the lower lip, and angle of the mouth* — need no particular description.

Alimentary Apparatus. *Teeth.* — The dental formula common to the Solipeda is as follows: —

Incisors $\frac{3—3}{3—3}$, canine $\frac{1—1}{1—1}$, premolars, $\frac{3—3}{3—3}$, molars, $\frac{3—3}{3—3}$ The canine teeth, however, it must be observed, only exist in the male sex.

The *incisor teeth*, in the generality of herbivorous quadrupeds, are bevelled off posteriorly, so as to present in front chisel-like cutting edges; but in the Solipeds, when young, the lateral incisors are furnished with two cutting edges, one in front and the other behind, from which circumstance those central fossæ are produced which, as we shall see further on, furnish important testimony relative to the age of the animal.

The *canine teeth*, here called "*tusks*," or "*tushes*," are always of very moderate dimensions, and their points, at an early age, become flattened and blunt. Those of the upper jaw are separated from the incisors by a considerable interval; and a similar interspace also exists, but to a less extent, in the lower jaw.

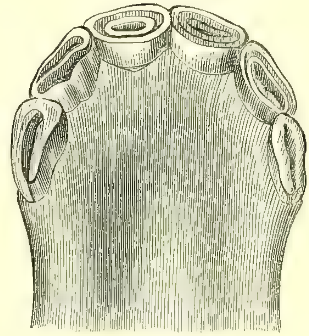
The *molar teeth* of the horse are of a prismatic form, their grinding surfaces being marked with four crescents of enamel in the lower jaw, and with five in the upper: these crescentic patches in the upper jaw have their concavities turned outwards, but in the lower jaw in the opposite direction. The teeth of the horse are, moreover, distinguishable from those of the ox and some other Ruminants, which they resemble in their general appearance, from the circumstance that, in the latter, the crescentic patches of enamel are arranged in pairs, and are placed parallel to each other; whilst in the horse they are situated alternately, the first of the inner margin of the tooth corresponding to the interval between the two of the outer margin.

Professor Owen * observes, that the character by which the horse's molars may be best distinguished from the teeth of other Herbivora corresponding with them in size, is the great length of the tooth before it divides into fangs. This division, indeed, does not begin to take place until much of the crown has been worn away; and thus, except in old horses, a considerable portion of the whole of the molar is implanted in the socket by an undivided base. The deciduous molars have shorter bodies, and sooner begin to develope roots; but in these, or in an old permanent molar with roots, the pattern of the grinding surface, though it be a little changed by partial obliteration of the enamel folds, yet generally retains as much of its character as to serve, with the form of the tooth, to distinguish such tooth from the permanent molar of a Ruminant.

A knowledge of the structure and history of the teeth of the horse becomes additionally important, from the circumstance that it is from the condition of the dental apparatus that an estimate may be formed concerning the age of the animal; and, in order to understand the data thus afforded, it will be necessary to consider the structure of these organs rather more closely.

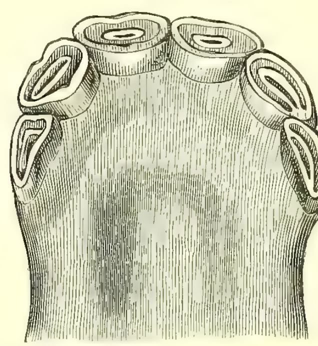
The incisors †, when the permanent teeth are first completely developed, are arranged close together, forming the arc of a circle at the extremity of both jaws; they are slightly curved, with long simple sub-trihedral fangs, tapering to their extremity. The crowns are broad, thick, and short; the contour of the biting surface, before it is much worn, approaching an ellipse. These teeth, if found detached, recent, or fossil, are distinguishable from those of the Ruminants by their greater curvature, and from those of all other animals by a fold of enamel, which penetrates the body of the crown from its broad flat summit, like the inverted finger of a glove. When the tooth begins to be worn, the fold forms an island of enamel, inclosing a cavity partly filled with cement, and partly by the discoloured substances of the food, and is called "*the mark*." In aged horses the incisors are worn down below the extent of the fold, and "the mark" disappears. The cavity is usu-

Fig. 505.



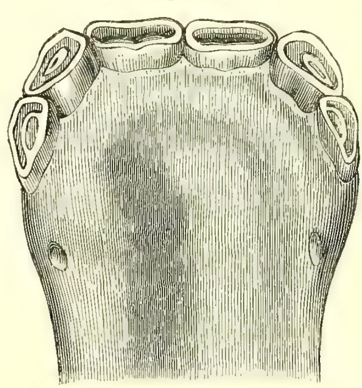
Lower jaw of a one-year-old Colt; milk incisors. (After Youatt.).

Fig. 506.



Two-years'-old; milk incisors, middle pair much worn. (After Youatt.)

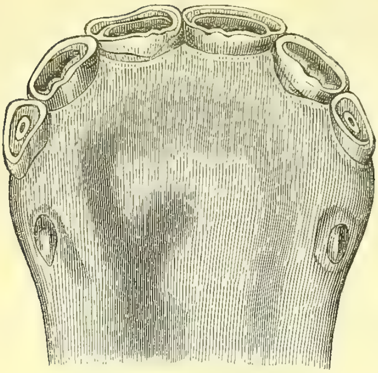
Fig. 507.



Three years; the two middle teeth have been shed and renewed; the canines just appearing above the gums. (After Youatt.)

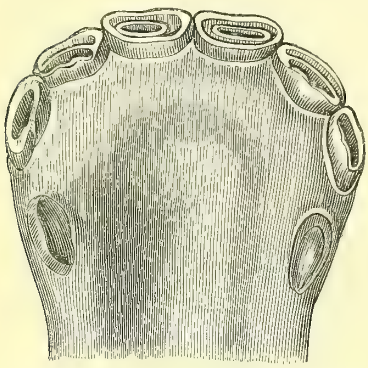
* Odontography, p. 574.
† Owen, Odontography, p. 572.

Fig. 508.



Four years; four teeth have been shed and renewed. (After Youatt.)

Fig. 509.



Five years; all the incisors have been shed and renewed; the middle pair much worn. (After Youatt.)

ally obliterated in the first, or mid-incisors, at the sixth year; in the second incisors at the seventh year, and in the third, or outer incisors, in the eighth year, in the lower jaw. It remains longer in those of the upper jaw, and in both the place of the "mark" continues for some years to be indicated by the dark-coloured cement, even to about sixteen years old. At this period the worn summits of the incisors present a subtriangular form.

The canine teeth are small in the horse, and rudimentary in the mare; the unworn crown is remarkable for the folding in of the anterior and posterior margins of enamel, which here includes an extremely thin layer of dentine. The representative of the first premolar in the first set of teeth is a very small and simple rudiment, and is soon shed. The three normal premolars are as large and complex as the true molars, the anterior one being usually the largest of the series in the upper jaw.

Salivary Glands. — The salivary apparatus in the Solipeda is very extensive, perhaps more so than in any other class of quadrupeds, consisting of large glandular masses divided into numerous lobes and lobules of a pale colour, and but loosely connected together by cellular tissue.

The *Parotid Glands* in the horse constitute a secreting apparatus, the bulk of which is extremely remarkable. Each of these glands extends from the external meatus auditoreus along the side of the head and of the lower jaw, as far forwards as the masseter muscle, and at the same time stretching deeply inwards as far as the side of the trachea. This enormous glandular organ may be considered as composed of three principal portions: each furnishing its excretory duct, which, however, soon unite to form a common canal, which at first descends within the angle of the jaw, whence, winding round the anterior edge of the masseter, it mounts up externally as far as the buccinator muscle, which it perforates nearly opposite the fourth molar tooth of the upper jaw, its internal orifice being situated in the centre of a prominent papilla.

The *Submaxillary Glands* are much smaller than the parotids. Posteriorly they consist of a thick globular portion, which is adherent to the inner surface of the parotid, but as they advance forwards, they become considerably attenuated, each terminating in its appropriate duct. The latter is of considerable length, and, after passing the sublingual gland, with which it contracts some attachments, opens into the mouth at a little distance behind the canine tooth, its opening being in the immediate vicinity of a papilla that seems to form a kind of valve at its orifice.

The *Sublingual Glands* are smaller than the preceding, and are of an oblong shape: they pour the saliva that they secrete into the cavity of the mouth through numerous orifices arranged in several rows on each side of the tongue.

In addition to the above large glandular organs, there remain to be noticed the *Molar Glands*, consisting of numerous detached granular-looking bodies of a lenticular shape situated beneath the mucous membrane that lines the buccinator muscle, and the inner surface of the superior maxillary bone behind which they mount up into the zygomatic fossa to within a little distance of the abductor muscle of the eye.

Pharynx. — The pharynx in quadrupeds generally presents a structure very similar to that of the human race, and may be said to be composed of analogous muscles: nevertheless its horizontal position in these animals renders the necessity for muscular exertion during deglutition greater than in man; and, accordingly, these fibres are not only stronger in quadrupeds than in our own persons, but sometimes additional muscles are met with, by the aid of which the action of swallowing is facilitated.

In the horse, the muscle which represents the *middle constrictor of the pharynx* might more properly be called the *pterygo-palato-*

pharyngeus *, its fibres descending from the pterygoid and palate bones, along the sides of the pharynx, around which they wind obliquely, uniting in the middle line upon its posterior surface, where they form a thick muscular layer.

The *inferior constrictor*, or *thyro-pharyngeus*, is equally broad and strong, its fleshy fibres taking nearly the same direction as they proceed towards the back of the pharynx, where they join by a median raphe.

In addition to the above, there is a *crico-pharyngeus*, arising from the posterior and inferior margin of the cricoid cartilage, whence its fibres extend obliquely upwards along the sides of the pharynx.

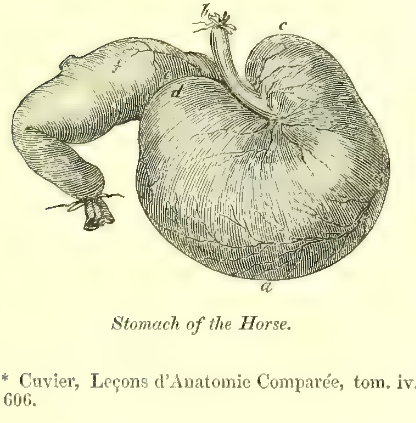
The analogue of the *stylo-pharyngeus* is, in the Solipeds, a cylindrical muscle derived from the styloid bone, and, running from behind forwards upon the sides and upper part of the pharynx, mixes its fibres with those of the superior constrictor — its action is to raise the commencement of the pharyngeal sac, which it at the same time dilates and draws backward.

There is likewise a small muscle derived from the middle part of the styloid bone, the fibres of which run backwards and inwards, so as to meet those of the muscle last mentioned.

Lastly, there are two other muscles, the fibres of which take a longitudinal direction. One of these, the *pharyngeus proprius*, arises from the tendinous middle line that extends from below the insertion of the stylo-pharyngei, and is prolonged downwards along the posterior and lateral walls of the œsophagus: the other, the *aryteno-pharyngeus*, is a small muscular band proceeding from the back part of each arytenoid cartilage, and running down the front of the œsophagus towards the stomach.

Stomach. — In all the Solipeda the stomach is simple, and presents little remarkable in its shape. The œsophagus (*fig.* 510. *b*) is inserted at a very acute angle into its smaller curvature, which is, as it were, folded upon itself. The cardiac cul-de-sac (*c*) is very capacious,

Fig. 510.



Stomach of the Horse.

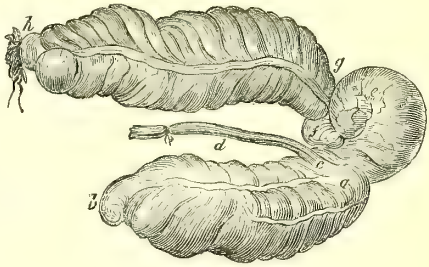
* Cuvier, Leçons d'Anatomie Comparée, tom. iv. p. 606.

and is lined throughout internally with a thick cuticular layer continuous with the lining of the œsophagus, and extends nearly as far as the middle of the stomachal cavity, where it terminates abruptly by a prominent indented edge, the interior of the pyloric half of the viscus (*a*, *d*) presenting the usual villous mucous surface. The muscular coat of the stomach consists of several superimposed layers of fibres that cross each other in different directions, some of them being apparently derivations from the muscular bands of the œsophagus; and it is doubtless the contractions of these muscular bands, in conjunction with the obliquity of the entrance of the œsophagus, that renders the act of vomiting impossible in these animals.

The alimentary canal in the Solipeds is short in comparison with that of the Ruminants and some other herbivorous quadrupeds; but this want of length is perhaps more than made up for by the enormous capacity of the large intestine, which, on first opening the body of one of these animals, seems of itself to occupy the whole of the abdominal cavity.

Commencing from the pylorus, the duodenum (*fig.* 510. *f.*) is found to be considerably

Fig. 511.

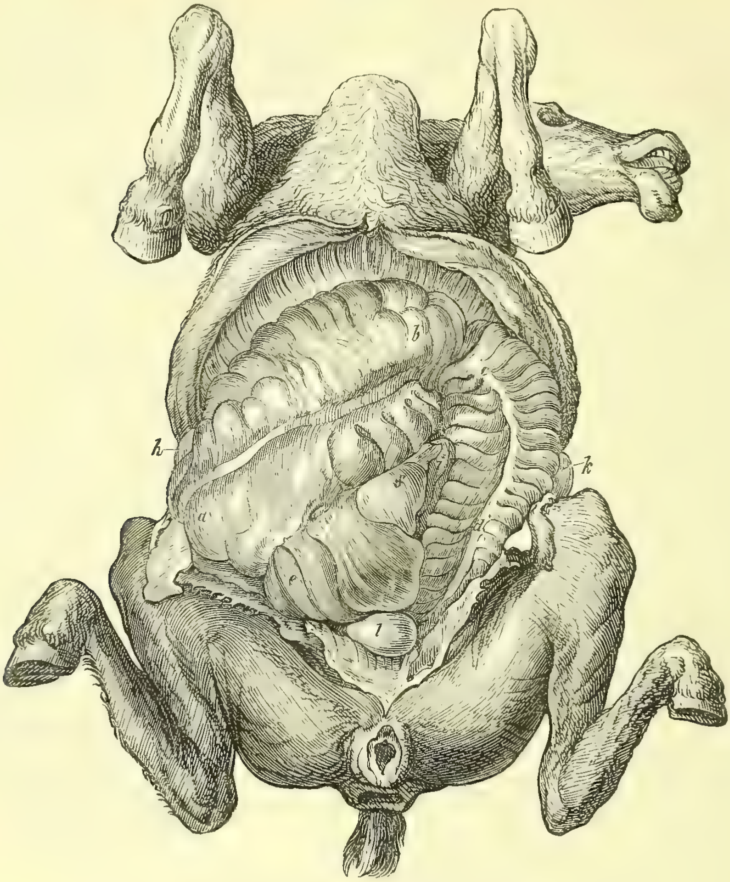


Caput Coli &c. of the Horse.

dilated; but its diameter soon contracts, and the rest of the tract of the small intestines is of pretty equable dimensions throughout, or if it presents constrictions here and there, they disappear when the gut is distended with air. The iliac portion of the small intestine (*fig.* 511. *d*) terminates in a cæcum of enormous bulk (*fig.* 511. *a*, *b*, *c*, *e*, *f*), which is separated from the commencement of the colon by a deep constriction (*g*): the colon itself is throughout its entire extent proportionately voluminous, commencing in the right flank: its ample folds (*fig.* 512. *a*, *b*) mount upwards as far as the diaphragm, whence they descend again, forming a viscus of vast capacity as far as the left iliac region, where, becoming gradually contracted in its dimensions, it terminates in the rectum. The ascending portion of the colon (*a*, *b*) is separated from the descending part (*c*, *d*) by a constriction; and the latter forms a third remarkable dilatation before it ends in the rectum. The whole colon is puckered up into huge sacculi by three longitudinal muscular bands, which terminate where the rectum begins, the last-named division of the alimentary canal presenting only a few pouches of comparatively small size, in which the fæces become moulded into balls preparatory to their expulsion.

When in a state of moderate distension, the

Fig. 512.



Colon of the Mare in Situ.

small intestines of an ordinary size are found to measure about fifty-six feet in length from the pylorus to the cæcum, with a circumference varying according to the state of contraction of the bowel from two inches and a half to six inches. The cæcum is about two feet and a half long, and about two feet in circumference at its broadest part; but towards its blind termination it assumes a conical form, and terminates in a point (*fig.* 511. *b*). Above the ileo-cæcal junction, the intestine forms a cul-de-sac (*fig.* 511. *e*), which is bent upon itself so as almost to resemble a second cæcum separated from the rest of the colon by a deep contraction, and there is, moreover, sometimes a third globular cavity, situated as shewn in *fig.* 511. *f*: but this is not constantly present.

The enormous colon (*fig.* 512. *a*, *b*, *c*, *d*), which seems of itself to occupy the whole abdominal cavity, is divided into two portions: — the first (*a*, *b*) is about 2 feet 3 inches long, and, at least, two feet in circumference; the second portion (*c*, *d*) is of nearly the same dimensions; but towards its termination, its circumference diminishes to 10 inches, and the continuation of the bowel retains that size for the length of a couple of feet, when it again enlarges to a circumference of 2 feet 4 inches before its termination in the rectum.

The entire length of the colon and rectum taken together is 21 feet, which, added to the length of the small intestines, gives a total length of 77 feet for the intestinal canal, exclusive of the cæcum.

Liver. — This viscus in the horse is divided pretty equally between the left and the right sides of the body. It is divided into four lobes, measures about a foot and a half in its greatest diameter, and weighs between four and five pounds. There is no gall-bladder; but the hepatic duct is extremely capacious, and evidently forms a receptacle for the biliary secretion.

Spleen. — The spleen of the horse has the shape of an elongated triangle, situated, obliquely, upon the left side of the stomach; its base pointing upwards and backwards, and its apex downwards and forwards; it is about 9 inches long, 4 inches broad at its widest part, and three-quarters of an inch in thickness. Its weight is about twelve ounces.

The *pancreas* is of an irregular shape, appearing to be made up of three branches — the shortest of which terminates at the duodenum; of the other two, one extends beneath the right, and the other reaches as far as the left kidney: these three branches form, by their union, a flattened mass, about half an inch in thickness, which may be called the body of the pancreas. There is nothing remarkable in the arrangement of its excretory duct.

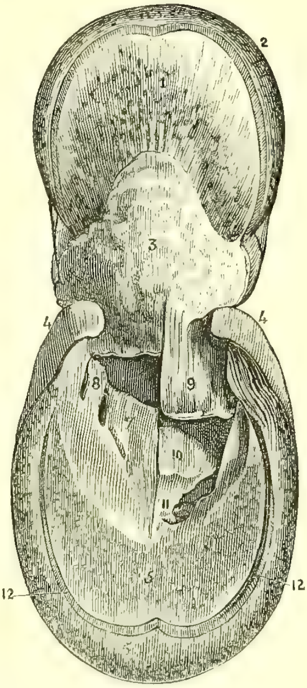
Circulatory Apparatus. — The structure of the *heart* and the general arrangement of the *arterial and venous systems* offer no peculiarities worthy of notice.

Structure of the Horse's Foot.—The mechanical structure of the foot of the horse demands to be considered at length, for in whatever point of view this part of their economy is regarded, either as a simple instrument of progression, or a curious piece of anatomy, it will be found equally deserving the study of the physiologist and of the veterinarian. Numerous writers have accordingly devoted their attention to this subject, both on the continent and in our own country; but their descriptions are, unfortunately, so mixed up with terms of farriery and stable jargon, that the anatomist finds considerable difficulty in deciphering their elaborate disquisitions. Among the most philosophical English treatises are those of Professor Coleman and Mr. Bracy Clark, to both of whom we shall be indebted for many of the following observations.

Horny hoof. — The whole exterior conical covering of the horse's foot, called in technical language the "wall of the hoof," is formed of a dense horny substance, which in shape resembles a hollow cone obliquely truncated at its upper part, so that the hoof is deepest or highest in front of the foot, diminishing in this respect as it recedes backwards towards the "quarters;" it then loses, to a considerable extent, its conical shape, and becomes nearly upright, especially on the inside or inner quarter, still growing narrower or lower to the posterior extremity of the foot, where, at first sight, it appears to terminate by mixing with the substance of the "frog," hereafter to be described, and with the integuments of the posterior region of the foot: instead of terminating in this manner, however, a more accurate examination shows it to be suddenly inflected inwards, pursuing its course towards the centre of the foot, where, diminishing gradually in depth, it is finally lost, becoming mixed up with the "sole," near the point of the frog, thus forming a distinct and remarkable internal wall that supports the under parts of the foot, and at the same time protects, by its bold projection, the sole and the frog from an undue degree of pressure and contusion against the ground.

The parts thus formed by a continuation of the wall of the hoof beneath the foot, are called the "*bars of the foot*," and are frequently described with, and taken for, part of the "sole." The direction of this sloping floor serves to throw all superincumbent pressure outwards towards the sides of the foot, and at the same time leaves a triangular space, posteriorly, for the insertion of the frog (*fig.* 513.), which it likewise protects from injury.

Fig. 513.



Structure of the hoof of the Horse.

1, the sole; 2, section of the horny hoof; 3, upper surface of the frog; 4, 4, the horny heels; 5, Bars of the foot; 6, walls of the hoof; 7, 8, 9, 10, 11, boundaries of the vaulted space, in which the frog is lodged; 12, 12, the sensitive foot.

The wall thus constructed appears to form the basis of the mechanism of the hoof, to which all the other parts are subordinate, and, if so understood, will much facilitate our views of the nature and economy of its structure. Its inner surface is every where lined, as it were, with numerous elastic lamellæ that project internally, and arranged in parallel lines, proceeding downwards perpendicularly towards the front of the foot (*fig.* 514, 3.): these horny laminæ are, at least, five hundred in number, and afford, from the aggregate surface that they present, a very extensive superficies for the attachment of an equal number of similar processes, derived from the vascular surface that covers the coffin bone, with which they interdigitate in such a way that the pressure to which the foot is subjected, which if concentrated upon a small surface would inevitably cause the destruction of living tissues, becomes so diffused as to produce no inconvenient results.

The horny lamellæ above alluded to, when removed from the hoof, have little or no elasticity when drawn in a longitudinal direction; but when drawn transversely, they possess this quality in a very remarkable degree, more especially in resisting pressure applied in a direction outwards and downwards, to resist which, the arrangement of their fibres is, on close examination, found to be particularly adapted.

The whole horny hoof, if unravelled by maceration or long continued exposure, is found to be essentially composed of longitudinal corneous threads or hairs matted, and, as it were, strongly glued together, — a structure preeminently adapted to combine all the requirements of strength, elasticity, and toughness.

As it approaches the quarters and heels, the horny helmet encasing the foot diminishes in its thickness as well as in height, affording, by this means, a degree of pliancy, which here becomes as necessary as firmness and unyielding solidity were in the front of the organ; yet, even here, by the doubling in of the hoof towards the sole, a strong horny margin is left, which is admirably adapted to receive the principal bearing of this part of the foot, and to protect and defend the sole enclosed within its curvature.

Frog. — The triangular chasm left by the inflections of the wall towards the centre of the foot, is filled up by a very remarkable organ, named, in the language of farriery, the "frog," either from some fancied gross resemblance which it bears to that animal, or, more probably, by corruption, from the French "fourche" or "fourchette," Anglicè "fork," applied to the same structure. By Latin writers, it is generally known under a similar appellation, "furca," and by the Greeks was named "χελιδονα," from a similarity between its shape and that of a swallow.

This body, which externally has the appearance of a triangular mass of elastic horn, may not be inaptly compared to an elastic key-stone received into an elastic arch communicating in some cases, and admitting in all, the springing movements of which such an arch would be capable. Its bar, which, towards the heels, is thin and broadly spread out, possesses a considerable degree of flexibility, which is gradually lost in approaching the centre of the foot, where there is less occasion for movement.

The *base* of the frog lies between and connects together the two posterior incurvations of the hoof; it then passes over and envelopes those parts, restraining their action. The *sides* of the frog are united by applied surfaces to the upper edge of the arch formed by the sole, or more truly the bar formed by the continuation of the wall. Its *point* extends to or beyond the centre of the sole.

The frog recedes from pressure in the natural foot, by having its level within the level of the other parts of the under surface of the foot, taking a third rate or degree of bearing upon the ground: the *wall* first; the *bar* next projecting beyond it: its base also retires further from pressure than the other parts of it, and is protected by the projecting angles of the *horny* or *lower heel.*

On either side, the frog is bounded by deep longitudinal excavations or channels, named the *commissures of the frog;* the bottom or deepest part of these channels, forming the line of union of the frog with the bar, a space is thus afforded on either side of the frog, which, as an elastic body, would have been useless without it; for in vain would elasticity have been given to any part, unless sufficient room was also given for its expansion. Towards the heels, these commissures are of considerable width, and they are there arched over by horny prolongation, from the base of the frog, named the *arch of the commissure.* The other extremity of the commissure growing, by degrees, shallower, is lost in the level of the sole, before it approaches the arch of the frog.

Seen from without, the frog makes a bold projecting appearance, as though it were a solid body of horn; and the smiths, deceived by this appearance, entertain but indifferent notions of its real structure, and use their paring knives upon it much more freely than its thickness warrants; for it is in reality only an inverted arch of horn that is turned downwards and reversed in respect to the general arch formed by the sole and bar, so that its real thickness in horn is by no means so considerable as on a first view it would appear to be.

Examined from within—that is to say, when the foot has been drawn forth from the hoof—the frog presents an inverted triangular arch, so intimately connected with the bar and sole, that no one would suspect it of being a distinct or divisible part, one uniform uninterrupted surface being everywhere observable on this inside: it may, however, be exhibited as a distinct inserted part by making a horizontal section of the foot through the union of the bar with the side of the frog, when the difference of their structure and appearance, and the line of their applied surfaces become sufficiently visible and distinct. A hoof exposed to the weather will also be seen in its decay to separate at this part first, and thus readily show its distinctness from the rest of the hoof.

In a perfect, well-formed foot, undistorted by shoeing, Bracy Clark observes that "the base of the frog occupies a certain division of the general circle of the hoof, and that this division is about a sixth part of the whole circumference. By knowing this fact we are not only led to entertain more just notions of the form of the foot and the proportions of its parts, but it affords us also an easy means of forming a pretty accurate guess of what injury or diminution the foot has sustained at any period of the life of the horse without previously seeing the original state of the frog."

The wings or lateral processes above described, as extending from the base of the frog, not only enclose the posterior ends or doublings in of the hoof, but the same horn is continued around the whole upper edge or margin of the roof, forming a broad convex band, whose upper edge, projecting higher than the hoof itself, receives and covers over the terminating edge of the skin, where it meets the hoof, and thus protects this part from external injuries, to which it would otherwise be liable. Posteriorly it is of considerable breadth, and firmly connects the frog with the upper part of the slope of the horny heels, over which it likewise expands. This structure, first described by Bracy Clark, received from him the denomination of the " coronary frog-band."

In the centre of the frog, as viewed from the sole, is a considerable cavity, the edges of which are furnished with rising lips or prominent margins of the horn; this hollow is termed the *cleft of the frog*, and extends to a considerable depth. This cavity appears to serve the following useful purposes *: — 1st. It is a safeguard from rupture between the two halves or divisions into which the foot is almost separated. 2dly. By closing when pressure comes direct upon the underside of the foot, it prevents too much condensation of the horn at this part, and consequent pressure and a too solid resistance upon the soft parts beneath. 3dly. When the foot bears partially upon the ground, as by one side only, which will happen occasionally where the surface is irregular, it can extend along with that side of the foot without rupturing, by the greater liberty it thus affords to the part, while at the same time the strength of its margin secures it from laceration. 4thly. On loose soils this indent or cavity will doubtless assist in giving the foot a firmer hold by the irregularity it offers to the surface.

It is, however, upon the inner aspect of the hoof that the most remarkable part of this structure is to be observed, for when examined internally it is found that the external cleft is only the hollow base of a cone of stout horn of considerable size, which passes from it directly into the substance of the sensitive frog, and which, though completely imbedded in the soft parts, is nearly or quite as hard and tough as is the horn of the exterior of the frog which is exposed to the air. This remarkable provision seems to serve the purpose of uniting more firmly the two halves of which the foot of the solipeds at this part really consists, there being here an evident tendency, in the tegumentary defences of the horse's foot, towards that division which in the ruminating quadrupeds is completely carried out. This important cone of horn Bracy Clark named the *frogstay* or *bolt*, observing that, like an inserted tooth, it more firmly holds the horny to the sensitive frog, for while the sensitive frog falls into the inverted arch of the horny frog, and is thus held most firmly in its place, this part, entering in the opposite direction into the sensitive frog, serves reciprocally to confirm and fix these parts together, and preserve them from external injury and dislocation. An excellent view of this piece of anatomy is obtained by making a perpendicular section of the foot extending through the " heels and surrounding elastic matter."

* Bracy Clark, op. cit.

The Sole. — This is an irregular plate of horn, which serves to close up the space or great inferior opening described by the lower circumference of the wall, and makes the third member or part of the hoof. It is usually of an arched form, more or less flattened, its concavity being turned to the ground, so that its centre, which is the thinnest part, is by this means removed from the degree of external pressure which the sides or bottom part of the arch have to support.

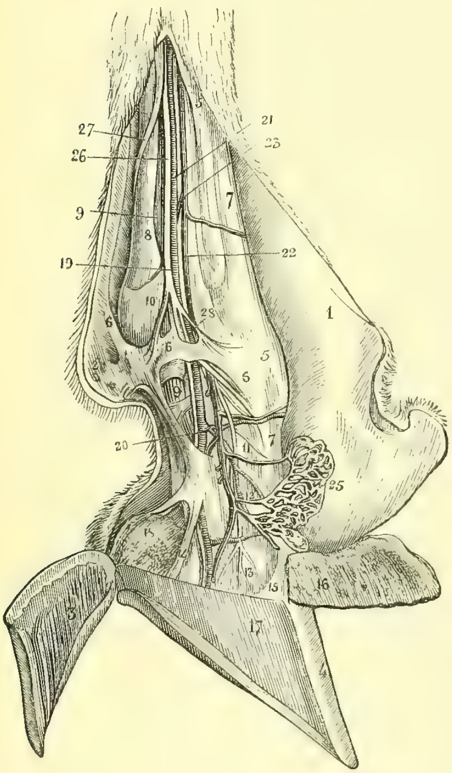
Nature has secured herself, by the arrangement of this part, in two ways from the resistance which an arch of common properties would create on becoming condensed under pressure, and forcibly resisting the load brought upon it, which would have been subversive of the leading principles of the mechanism of the hoof. In the first place the sole being cleft to its centre or beyond it by the large triangular opening formed at its posterior part, which, destroying the resistance of the arch, serves to receive the ends also of the wall of the hoof first, and is then closed and filled up by the inverted arch of the frog; so that the ends of the hoof are thus tied in and secured from being forced asunder by the pressure from within, being thus wedged in between the frog and the sole, serving in their places the other offices already noticed, while the sole, being thus broken, has a diminished resistance in the centre.

Again: the lower circumference of the arch of the sole is everywhere found abutting against the sides of the wall, which are rendered sufficiently flexible outwards to yield to the weight when pressed against by the descent and flattening of the sole, so that every provision for the elasticity of the foot is thus fully secured.

The horse's hoof is therefore fully provided with the means of preserving its form; but this power is unfortunately grievously interfered with by the process of shoeing; and it is in this country at least a very rare occurrence to obtain an opportunity of examining a foot in its full-grown natural condition.

From the above description of the foot of the horse it will be seen that, although when viewed in front it appears to be solid and single, the terms *Solidungula* and *Solipes* convey but a very imperfect notion of the real nature of this kind of hoof; for though the front be solid the posterior parts possess the greatest degree of elasticity, short of being actually cloven, that can be imagined from the sole being open to its centre and filled up with the frog. In such a foot as the term Solidungula would imply, or a continuous circle of horn, no animal could long stand, much less move, without great fatigue and pain from compression, which would soon become destructive. If it were necessary to employ any single epithet to express the real nature of this kind of locomotive apparatus, Bracy Clark suggests that the term *Semifissipes*, or half-cloven foot, would be less objectionable, though also not exactly true, on account of the presence of the frog, which, added to the entire hoof in front, seems to afford the most essential character of this kind of foot.

Fig. 514.



Dissection of the superficial Parts of the Horse's Foot.

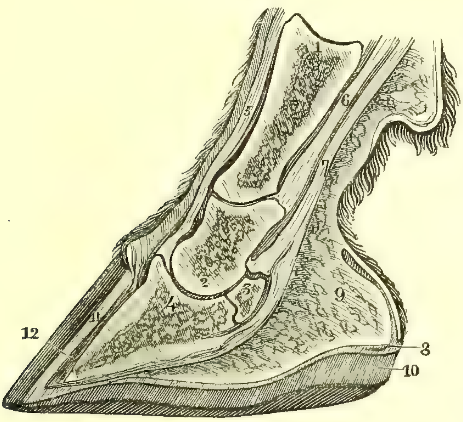
1, General integument; 2, fatty mass, forming a cushion behind the great pastern joint; 3, wall of the hoof turned back, showing the vertically lamellated horny processes projecting from its inner surface; 4, section of the wall of the hoof; 5, articulation between the cannon bone and the great pastern; 6, 6, 6, aponeurotic tissues; 7, 7, tendon of the extensor longus digiti pedis. 8, 9, 10, the flexor tendons of the foot; 11, 12, 13, 14, 15, expansions of the great anterior cartilage of the foot; 16, the coronary frog-band raised from the hoof; 17, the vascular or sensitive hoof; 18, elastic cushion of the heels; 19, 20, 21, arteria plantaris; 22, 23, plantar veins; 25, part of the coronary venous plexus raised from its position; 26, 27, 28, plantar nerves.

Cartilages of the Foot. — On removing the hoof there are seen immediately beneath it two large elastic cartilages ranging to a great extent along both sides of the foot. Their figure is almost too irregular for comparison; but, when seen on a lateral view of the foot, their shape may be said to resemble that of a lozenge or of a pretty fully expanded fan, fixed by its centre, which is very much thicker and more solid than the other parts, in a deep horizontal cavity or channel in the coffin bone provided for its reception; from this central point of insertion the anterior portion of it, passing forward, nearly meets the cartilage of the opposite side in front of the foot, the great extensor tendon of the foot only separating them, with which they are likewise connected, and make a common surface. On its inside this extremity of the cartilage takes a strong adherence to the condyles of the coronary bone, and so closely surrounds the joint betwixt the latter and the coffin bone that the articulation appears to be without any capsular ligament at this part. The posterior portion of the cartilage, ranging more largely and becoming thinner as it expands itself backwards, growing at the same time more elastic in its texture, is gradually and inseparably mixed up towards the hinder part of the foot with the skin and the ligamentary elastic tissues that form the "upper heels," and constitute the principal materials for elasticity in these parts. Spreading also in an upward direction to a considerable height above the hoof, it terminates by a rounded, thin, and irregular edge, which is inflected inwards over the soft interior of the foot, to which it forms a kind of roofing and defence.

Next, this widely distributed cartilage may be observed passing downwards, and surrounding on every side the rough and knotty extremities of the heels of the coffin bone, entering and filling up its sinuosities, and taking strong adherence to these processes; it then extends itself horizontally inwards, passing over the horny sole and bar, and, meeting the side of the sensitive frog, intimately unites with it, forming one inseparable mass, and together filling up the whole internal area described by the sides of the coffin bone. The upright or lateral portion of the cartilage forms, with this horizontal process inwards, a right angle, thus making together a hollow space or receptacle at the back of the coffin bone, that contains the spongy elastic stuffing of the heels, together with the tendons, trunks of bloodvessels, nerves &c., passing through this part to the sole of the foot. The upper surface of the horizontal process of cartilage is full of scabrous elevations and depressions that defy dissection, among which there exists a quantity of a gelatino-ligamentous material. Beneath, or to the under surface of this horizontal layer of cartilage, the sensitive sole and bar are adherent; and, in approaching the frog, or centre of the foot, it loses its cartilaginous nature, and becomes coriaceous, or rather ligamento-coriaceous, in texture, agreeing in this with the internal frog.

The horizontal portion or process of the cartilage, named by veterinary writers the "*stratiform process*," is of greater thickness and substance than the other parts; it is also of a coarser grain and more elastic nature; both portions together communicate the general boundary and form to the lateral, the posterior, and inferior parts of the foot; and when the bars or frog are thrust upwards by pressure from without, they are then acting against this same horizontal flooring, formed by the cartilage and the frog, and met by the depression of the bones of the foot forced down from the weight of the animal; the whole can then dilate exteriorly along with the posterior and more elastic parts of the hoof.

Fig. 515.



Longitudinal Section of the Foot of the Horse.

1, Great pastern bone; 2, lesser pastern or coronary bone; 3, sesamoid bone implanted in the flexor tendon of the last phalanx; 4, coffin bone; 5, tendon of extensor digiti; 6, tendon of flexor sublimus; 7, tendon of flexor profundus; 8, section of the posterior expansion of the great cartilage; 9, soft cushion of the heel; 10, section of horny hoof; 11, sensitive hoof; 12, anterior section of the cartilage spreading over the coffin bone.

The objects attained by the introduction of this admirable structure into the foot of the soliped are various, and have been well pointed out by Bracy Clark, in his excellent treatise, to which we must refer the reader for many practical applications connected with the veterinary art, that would be foreign to the objects of the present article. First, seeing that the resistance of a solid unyielding support would have been inadmissible, the pedal cartilages are employed as a substitute for bone, and made to occupy a very large share in the composition of the hinder part of the foot; for it will be remarked, the coffin bone, except by its extremity, does not extend beyond the middle of the hoof (*fig.* 515.), the posterior shape of the foot being almost wholly communicated by the cartilage, which, passing nearly around the whole coronary circle, serves to support and convey the skin to its lodgment in the coronary concavity of the hoof. Secondly, it serves to equalise the pressure every where over the internal surface of the hoof when under the pressure of the weight from within, during the descent of the bones of the foot, and, what is singular, the hoof itself is the most solid material of these hind parts of the foot.

A more important office still remains to be explained, namely, that of supplying the coffin bone with a considerable share of its capability of motion in the interior of the hoof; for it is to be remarked that, as the coffin bone is obliged to describe in its descent a small portion or segment of a circle, at its back part, round its centre of motion, or rather its more fixed part (for there is none of it wholly fixed), towards the front of the foot; so this could not so well have been accomplished had the bone itself been fixed at its upper part to the processes in front of the hoof, these being too inconsiderable to afford, in that part of the bone, the extent of motion required; but, by the intervention of an elastic cartilage between the bone and the substance of the hoof, the bone acquires greater liberty for action, and movement of its upper parts.

The cartilages of the foot, in old horses, not unfrequently become partially ossified, in which condition they are known to farriers by the name of ring-bones.

Soft Parts of the Foot. — On removing the hoof, and its horny appendages situated beneath the sole of the foot, the whole subjacent surface is found to consist of a thick, villous looking, and highly vascular membrane, moulded exactly to its inner surface, to which the name of *sensitive foot* is generally applied; or, according to the structures beneath which it is situated, it is sometimes divided into sensitive hoof, sensitive frog, &c. This structure is, indeed, the matrix from which the entire corneous hoof derives its origin, and is essentially similar, in its texture and functions, to the soft core upon which the hollow horns of many ruminants and the vascular secreting surfaces upon which the nails and claws of unguiculate quadrupeds are formed. Externally it presents, upon the anterior surface of the foot, the broad vascular laminæ which interdigitate with the horny plates, projecting from the interior of the hoof, as described above, so as to amplify, to a very considerable amount, the extent of surface whereby the contact between the sensitive foot and the wall is effected.

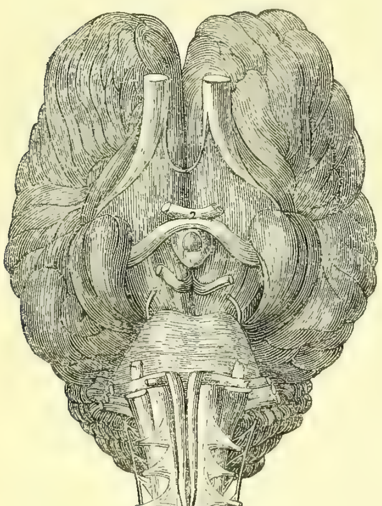
This entire surface is richly supplied with nerves and bloodvessels, the latter of which open into capacious plexuses, that surmount the coronary margin of the hoof (*fig.* 514.), and, when injected, present a very beautiful appearance.

Nervous System and Organs of the Senses. — The general arrangement of the nervous system and structure of the organs of sensation offer in the class before us no peculiarities of sufficient physiological importance to require a detailed description: we append, however, figures representing the cerebral convolutions and the base of the encephalon of the horse for comparison with similar figures given in other articles.

Fig. 516.

Brain of the Horse, showing the Convolutions.

Fig. 517.



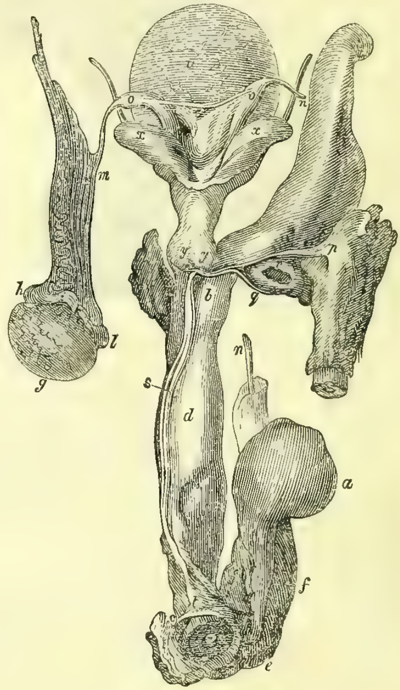
Base of the Brain of the Horse, showing the origin of the Cerebral Nerves.

Organs of Generation. *Male Generative Organs.* — The external organs of generation in the male solipeds are remarkable for their great development, and in nearly equal proportion are these animals conspicuous for their vigorous and fruitful generative powers, which, however, are only called into full activity at a certain season of the year, namely, in this climate, from the beginning of April till the latter end of June, during which period he will efficiently serve fifteen or eighteen mares.

The *scrotum* is suspended between the thighs at a distance of about nine inches beneath the anus, whence it is prolonged forwards, to terminate in the prepuce (*fig.* 518. *a, f, e*).

The *penis* (*fig.* 518. *b, c, d*) is full a foot in length even in its undistended state, measuring from the bifurcation of the corpora cavernosa (*b*) to the extremity of the glans (*c*), which latter organ is itself nearly half a foot in length, and four inches in circumference; its shape is cylindrical, and it is covered with a soft and smooth skin.

Fig. 518.



Organs of generation of the Stallion.
(After Daubenton.)

a, the scrotum; *b, c, d*, the penis; *e*, the prepuce; *f, f*, the rudimentary mammæ; *g*, the left testicle removed from the scrotum; *h*, the epididymus; *i, k*, the upper margin of the testis; *l, m*, vas deferens; *n*, vas deferens from the opposite side; *o, o*, enlargements of the vas deferens before their termination; *p, q*, tendinous bands derived from the root of the tail, these, after embracing the end of the rectum, *r*, run along the penis, *s*, as far as the prepuce, *t*, where they terminate; *v*, the urinary bladder; *x, x*, vesiculæ seminales; *y, y*, Cowper's glands.

The *testicles* (one of which only (*g*) is represented in the figure) are of an ovoid flattened form, each being about three inches long by two inches broad, and one inch and a half thick: the *epididymus* (*h*) issues from its anterior part, and is composed of large tubes of a yellowish colour, bound up together in numerous small bundles. Arrived at the posterior extremity of the testes, the epididymus folds back upon itself, to constitute the vas deferens; which, at its commencement, is very tortuous, and forms a protuberance of considerable size (*l*). The *vasa deferentia* (*l*, *m*, *n*) are upwards of fourteen inches in length, and, during the greater part of their course, about two lines in diameter; but towards their termination they become, for a length of about seven inches, much dilated, here measuring upwards of fifteen lines in circumference (*o o*). The caliber of the internal canal does not, however, expand in proportion to the dilatation of the exterior of the duct.

Female Organs of Generation.— The generative organs in the female solipeds offer no variations of structure from the usual type common to placental quadrupeds. The *clitoris* (*fig.* 519. *a*) is of great size, and is lodged in a cavity appropriated to its reception, situated immediately above the inferior (*i. e.* anterior) commissure of the labia pudendi; its glans is enclosed in an ample prepuce, above which may be observed an orifice leading into a cavity big enough to lodge a small bean. The canal of the *vagina* is about a foot in length, and in its capacity corresponds with the ample dimensions of the penis of the other sex.

Immediately behind the orifice of the urethra, the mucous membrane of the vagina forms a broad fold, which is directed forwards and lies immediately over the urethral opening: the length of this fold in the adult mare is about eight inches, and, near its middle, it is upwards of an inch in breadth.

The *urinary bladder* is small in comparison with the size of the animal; its shape is nearly round; and its circumference, when moderately distended, about a foot and a half. The urethra is remarkably short and capacious, the circumference of its canal being about three inches, while its length is only about an inch and a quarter.

The *orifice of the uterus* (*i*) projects to the distance of about half an inch into the upper end of the vagina, and is of a rounded shape, encircled by a thick margin. The womb is made up of the body and two cornua, which latter, in the unimpregnated state, measure about seven inches in length.

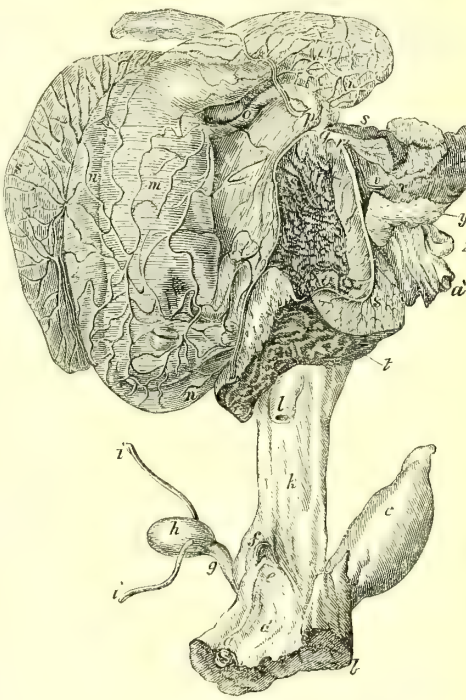
The *ovaria* and *fallopian tubes* present nothing remarkable in their structure or arrangement.

Gravid Uterus.— The anatomy of the contents of the gravid uterus, and the arrangement of the membranes that enclose the fœtus offer some peculiarities worthy of notice.

The fœtus in utero in the solipeds, is enveloped in the usual uterine membranes,— the amnion, the chorion, and the allantoid; but the disposition of these envelopes differs remarkably from what exists in the ruminants, and many other quadrupeds.

The *urachus* (*fig.* 520. *a*) issues from the umbilicus in company with the umbilical arteries and vein (*b*), and, in the ovum represented in the figure, was found at some distance from the umbilical opening to measure about five inches in circumference, beyond which point its diameter gradually diminishes, till it reaches the point at which the amnion spreads out on all sides to envelope the fœtus, where it terminates by the orifice *e*, and is prolonged to form the allantoid, which encompasses the rest of the cord. On the arrival of the allantoid at the extremity of the cord, it extends itself upon the chorion to which it becomes adherent, lining its internal surface in such a manner, that the two seem to form but a single membrane, the inner surface of which is formed by the allantoid (*g*), its exterior by the chorion (*h*).

Fig. 519.



Organs of generation and gravid uterus of the mare. Vagina laid open. (*After Daubenton.*)

a, the clitoris; *b*, anus; *c*, rectum; *d*, posterior surface of the vagina; *e*, the orifice of the urethra; *f*, membrane which covers the urethral opening; *g*, the canal of the urethra; *h*, the bladder; *i*, *i*, the ureters; *k*. continuation of the vagina; *l*, orifice of the womb; *m*, fœtus as seen through the transparent amnion, *n*; *o*, portion of the umbilical cord that extends from the umbilicus of the fœtus as far as *p*, the point where the amnion spreads out; *q*, portion of the umbilical cord which extends beyond the amnion to the point *r*, where the chorion and the allantoid become united; *s*, the allantoid; *t*, the chorion seen from its outer surface; *v*, a hippomanes attached by its pedicle; *x*, *y*, chorion adherent to the uterine walls by numerous rugæ; *z*, the left ovarium; *a'*, the spermatic vessels.

The size of the umbilical cord gradually enlarges as it approaches the chorion, owing to the progressive dilatation of the vessels composing it as they recede from the umbilicus.

The *allantoid* in the mare does not form a closed bag, as it does in the ruminants, but lines about half of the interior of the cavity that exists between the amnion and the chorion. To form an idea of this cavity and of the space occupied by the allantoid, it will be necessary first of all to consider the amnion as a sac, in which the fœtus is enclosed, and the allantoid and the chorion as forming another sac of larger size, by which the former is enveloped in such a manner, that an interspace is left between the two : this interspace is traversed by the second portion of the umbilical cord as it passes from the former sac towards the latter, and in this course, the cord is enveloped by the allantoid membrane, which subsequently invests all the interior of the second sac formed externally by the chorion.

Fig. 520.

Anatomy of the gravid uteris of the mare. (*After Daubenton.*)

a, the urachus emerging from the umbilical opening of the fœtus, accompanied by the umbilical vein; *b*, and by two umbilical arteries; *c*, continuation of the umbilical cord as far as the expansion of the amnion; *d*, *d*, *e*, termination of the urachus; *f*, continuation of the umbilical cord; *g*, *g*, allantois; *h*, the chorion; *i*, an hippomanes adherent to the allantoid by its pedicle; *k*, *l*, *m*, two other hippomanes of smaller size. The other letters refer to the generative organs of the fœtus (a female) shown in connection with the above parts; *o*, the rectum; *p*, the anus; *q*, the bladder of urine communicating with the urachus; *r*, *r*, the ureters; *s*, canal of the vagina; *t*, orifice of the urethra; *v*, first appearance of the membrane, which subsequently spreads over the urethral orifice; *x*, *x*, the cornua uteri; *y*, separation between their internal cavities; *z*, *z*, the ovaria.

The aperture of the urachus pours forth a glairy fluid of a reddish colour, which is received into the cavity, the boundaries of which are described above: this fluid has a urinous smell, especially when heated, and moreover contains certain solid bodies, which have been from time immemorial dignified with the name of *hippomanes*, and were by the ancients supposed to be possessed of various mysterious qualities, and magical influences.

The *Hippomanes* was considered, until a very recent period, to be a piece of flesh growing upon the forehead of the nascent foal; and it was not until Daubenton presented a memoir upon this subject to the Royal Academy of Sciences in Paris *, that its real nature was understood. The hippomanes were then found to be merely masses, of a thick substance, of variable dimensions, contained in the allantoid cavity, which, although they might occasionally during parturition after the laceration of the membranes, become adherent to the head of the fœtus, are, in reality, produced between the amnion and the allantoid membranes.

These bodies are very variable in their size, and frequently several are met with, the dimensions of which vary from the size of a pea to that of a large pear, some of the latter weighing as much as five or six ounces. They are composed of a viscid substance of an olive brown colour, and frequently have irregularly shaped cavities in their interior; but they present no traces of organization. When cut into they seem to be made up of numerous superposed layers, and externally their surface is covered with floating filaments : sometimes they are found to be attached by long pedicles to the walls of the allantoic cavity ; but, whatever their shape, they are evidently merely sedimentary deposits from the fluid in which they are immersed, and indeed may be formed at pleasure by slowly evaporating the contents of the allantoic sac. These structures are indeed by no means peculiar to the horse, but are frequently met with in other animals.

The exterior of the chorion is everywhere in contact with the uterine walls, and in shape represents exactly the interior of the cornua uteri, upon which it is moulded, the placenta occupying the greater portion of its extent.

Mammary Glands.—It was generally believed from the time of Aristotle until a very recent period, that in the male horse there were no nipples or other rudiments of the

* Mémoires de l'Académie Royale des Sciences, années 1751 and 1752.

female mammæ; except, as Aristotle expresses it, in such animals as resemble their mothers*: that is to say, in other words, that there were a few exceptional cases. Subsequent authors have stated the same concerning male solipeds in general†, although none stated in what the resemblance consisted, or where the mammæ in those furnished with them were situated; so that even Buffon asserted it as a fact, that the male solipeds had no vestiges of mammæ. Daubenton, however, having previously discovered the situation of these organs in the male ass, was led from analogy to expect their presence in the horse likewise, and soon detected them, but situated in a very unusual position, — namely, upon the prepuce of the animal. The prepuce of the stallion is found to form a kind of prominent ring around the aperture through which the penis is protruded, and it is upon this circular protuberance, close to the sides of the scrotum, that the mammæ are situated. These organs are two in number (*fig.* 518. *ff*), situated at a distance of about half an inch from each other, and are easily distinguishable from the circumstance of the skin being raised into a papilla around each nipple, in the centre of which there is a shallow depression. It would seem, however, that in old horses the presence of these rudimentary mammæ becomes less apparent.

In the mare, the mammary glands are situated between the thighs at a distance of about nine inches in front of the vulva. The nipples are only two in number, one on each side of the mesial line, and their distance from each other is not more than an inch and a half. As in the goat and many herbivorous quadrupeds, all the lactiferous ducts form, in the base of each gland just above the root of the nipple, a large hollow cavity, which is divided by an internal septum into two chambers, one situated in front, and the other behind; from each chamber a separate duct is derived, which passes along the nipple as far as its extremity, where it terminates. The orifices of these canals are situated, one behind, the other about a line, apart. It is owing to the presence of the reservoirs thus formed by the cavities of the mammary glands, that the lacteal secretion is permitted to accumulate in considerable quantities, until required for the nourishment of the young, or removed by human agency for the purpose of procuring the milk, which is frequently employed as an article of diet.

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(*T. Rymer Jones.*)

* *Equi mammas non habent, nisi qui matri similes prodiere.* — Arist. de Partib. Anim. lib. iv. cap. 9.

† *Solidungula mascula mammas non habent præterea quæ matribus similia sunt.* — Rai, Synops. method. Anim. quad. &c. p. 64.

SPINAL ACCESSORY NERVE (part of the sixth pair of the older anatomists; part of the eighth pair of Willis; *nervus accessorius ad par vagum; nervus accessorius Willisii*; the eleventh pair of Soemmering; the *beinerve* of the German anatomists). This nerve is attached to, or, as it is more commonly expressed, arises from, the lateral surface of the cervical portion of the spinal chord close to the posterior roots of the spinal nerves; and it lies between the posterior roots of the spinal nerves and the ligamentum denticulatum. On entering the cranium by the foramen magnum, it continues to receive additional roots or filaments of origin from the medulla oblongata. It commences by a very slender filament, most generally opposite the fifth or sixth posterior roots of the spinal nerves, and in its passage upwards to the interior of the cranium, its bulk is gradually increased by additional filaments of origin from the lateral surface of the spinal chord and from the medulla oblongata. The filaments arising from the spinal chord pass upwards and a little forward to join the trunk of the nerve, so that it lies a little nearer to the ligamentum denticulatum than the attachments of the filaments forming it. After it enters the cranium by the foramen magnum, it runs forward, outward, and upward, places itself in close apposition to the posterior surface of the par vagum, and escapes from the interior of the cranium, through the foramen lacerum posterius, along with the vagus and glossopharyngeal nerves. The roots of the accessory that arise from the medulla oblongata are placed in the same line with the lower roots or filaments of origin of the par vagum; and the upper roots of the former approach so closely to the lower roots of the latter, that it is frequently difficult to say with confidence where the roots of the one nerve end and those of the other begin. (*Fig.* 521, 3, 5.)

Previous to the time of Willis, anatomists considered this nerve as constituting a part of the vagus, and to him is due the credit of first pointing out clearly the grounds on which its separation from the vagus rests. Very great discrepancy exists in the description of the origin of this nerve given by the best anatomists. This is explained, not only by the fact first pointed out particularly by Scarpa*, that its filaments of origin are attached over different extents of the spinal chord in different individuals, and sometimes to a greater extent on one side than on the other in the same individual, but also by its lower roots or filaments of origin being so slender that they sometimes cannot be accurately traced by the naked eye. Willis himself describes it as commencing by a very slender beginning near the sixth or seventh cervical nerve.† Scarpa ascertained that its

* Abhandlung über den zum achten Paare der Gehirnerven hinlaufenden Beinerven. In den Abhandlung der röm. K. K. Josephinischen Med. Chir. Academie, Band i. Wien, 1787.

† Cerebri Anatome, &c., Caput xxviii. p. 294. Amstelodami, 1666.

lowest root may be attached to the spinal chord opposite the fourth, fifth, sixth, or seventh cervical nerve, but more frequently between the fifth and sixth; and that when its roots are extended over a more limited portion of the spinal chord, this is compensated for by their being proportionally stronger.*

Anatomists have differed as widely in their account of the particular column or tract of the spinal chord to which the roots of the spinal accessory are attached, as they have done regarding the extent of the spinal chord over which these roots stretch. This is a point in the anatomy of the nerve which has assumed greater importance since the discovery by Sir Charles Bell, of the separate functions of the anterior and posterior roots of the spinal nerves, and is of much more interest to the modern, than it was to the older anatomists. The filaments of origin or roots of this nerve that come from the spinal chord are attached to the chord near the posterior lateral groove separating its posterior and middle columns, and close upon the posterior roots of the spinal nerves, so that we can readily understand how some anatomists should describe these roots as arising from the middle column, and others describe them as springing from the posterior column.† Among the modern anatomists we find Bellingeri, who has attended particularly to the anatomy of this nerve, describing it as arising from the middle or lateral column of the spinal chord*, while Bischoff† and Bernard‡ trace its origin to the posterior column; and Bendz§ states that while nearly the whole of its roots come from the middle column, a few arise between the posterior roots of the spinal nerves and from the posterior column.‖ From my own examinations of the attachments of this nerve, I had arrived at the conclusion that it arises from the posterior part of the middle column, and that its middle and inferior roots are attached along the course of the decussating fibres of the pyramidal column, which form the posterior part of the middle column of the chord.¶ Stilling says** that the lower and middle roots of this nerve can be traced to the anterior grey substances in the chord, from which the anterior roots of the spinal nerves arise, and that, in an anatomical point of view, they must be regarded as performing the same functions as the anterior roots of the spinal nerves; while the upper roots, or those which are attached to the medulla oblongata, differ in a marked manner, in regard to their origin, from the lower and middle roots. He states that these upper roots above the first cervical nerve arise from a grey mass in the medulla oblongata, which he styles the *accessory-kernel* (accessorius-kern††), and that they resemble closely the lower filaments of origin of the par vagum. These upper roots of the accessory do not arise from the gelatinous substance from which, according to Stilling, the posterior roots of the spinal nerves spring, yet they come into closer relation with it the nearer they approach to the commencement of the roots of the vagus. The upper fibres of the accessory, though not continuous with the posterior roots of the spinal nerves, are yet, he believes, analogous to these; and this view is strengthened by their presenting the same connection with the roots of the hypoglossal as is found between the roots of

* Huber (De Medulla Spinali, et speciatim de Nervis ab eâ provenientibus, p. 13.) says that this nerve commences opposite the seventh cervical, but he afterwards speaks of it arising opposite the sixth. Lobstein (De Nervo Spinali ad Par Vagum Accessorio, p. 233, as reprinted in Ludwig's Script. Neurol. Min. Selec. tom. ii. Lipsiæ, 1792) describes it as arising under the sixth pair of cervical nerves by a slender beginning. Bellingeri (De Medulla Spinali, Nervisque ex eâ prodeuntibus, p. 74, 1823) places its origin opposite the seventh cervical nerve. Cruveilhier (Anatomie Déscriptive, tom. iv. p. 899, 1835) says that its origin seldom passes below the level of the fifth pair of cervical nerves, but it may arise opposite the sixth and even the seventh pair. Bendz (De Connexu inter Nervum Vagum et Accessorium Willisii, p. 22, 1836) describes its lowest root as arising from the spinal chord in the region of the fifth or sixth cervical nerves, and rarely as low as the posterior root of the seventh cervical. Valentin (Soemmering vom Baue des menschlichen Körpers. Hirn und Nervenlehre, S. 513, 1841) states that its most frequent origin is opposite the sixth, or between the sixth and seventh cervical nerves; sometimes it arises opposite the fourth or fifth, or it may extend as far as the seventh, and in rare cases as far as the first dorsal. Krause (Handbuch der menchlichen Anatomie, Erster Band, S. 1066: Hannover, 1842) says that it usually arises opposite the upper part of the roots of the seventh cervical, seldom higher. Bernard (Archives Génerales de Médecine, 4ième sérіe, tom. iv. p. 410, 1844) describes it as arising by a series of bifid or trifid nervous filaments, which extend, in man, from the origin of the pneumogastric to a point opposite the fourth or fifth pair of cervical nerves.

† Rolando (Recherches Anatomiques sur la Moëlle Ablongée) and Serres (Anatomie Comparée du Cerveau, tom. i.) have stated that the lower fibres of this nerve come from the anterior column of the spinal chord.

* De Medulla Spinali, Nervisque ex eâ prodeuntibus, pp. 51. 55, 1823.

† Nervi Accessorii Willisii Anatomia et Physiologia, p. 11. Darmstadii, 1832.

‡ Archives Génerales de Médecine, 4ième serie, tom. iv. pp. 409, 410, 1844.

§ Tractatus de Connexu inter Nervum Vagum et Accessorium Willisii, pp. 22. 39. Hauniae, 1836.

‖ Lobstein (De Nervo Spinali, in Ludwig's Scriptores Nevrologici Minores Selecti, tom. ii. p. 233.) also describes some of the filaments of origin of the spinal accessory as coming from the spinal chord between the fasciculi which constitute the posterior roots of the spinal nerves, and has represented these in *fig.* 1. Those who may wish to ascertain the opinions of other anatomists as to the particular column of the spinal chord into which this nerve is implanted, and the extent of its attachment to the cervical portion of the spinal chord, may consult the monographs of Bischoff and Bendz quoted above, and especially that of the former of these authors.

¶ On some points in the anatomy of the medulla oblongata, in Edinburgh Medical and Surgical Journal for 1841.

** Ueber die Textur und Function der Medulla Oblongata, pp. 55. 57. Erlangen, 1843.

†† He describes the position and structure of this accessorius-kern at p. 23. of the work quoted.

the posterior and anterior spinal nerves at their origin.

The spinal accessory in its course within the spinal canal frequently forms communications with the posterior root of the first cervical, and much more seldom with the posterior root of the second cervical nerve.* When these communicating filaments come from the second cervical, they are generally few in number. This communication between the spinal accessory and the posterior root of the first cervical is, according to Lobstein, more frequently present than absent.† When the posterior root of the first cervical joins itself, either in whole or in part, to the spinal accessory, a branch of equal size generally leaves the accessory, either at the point where it is joined by the posterior root of the first cervical, as figured and described by Asch ‡, or a little above this junction, as figured by Huber §, and described by Bellingeri.|| This branch, after leaving the accessory, proceeds outwards, approaches the anterior root of the first cervical, and takes the place of the posterior root of that nerve.¶ When the posterior root comes from the accessory, it generally presents a ganglion in the usual position. Sometimes, however, though rarely, this ganglion is found on the accessory where the posterior root of the first cervical leaves it to join itself to the anterior root. This ganglion was first pointed out by Huber; its existence has been denied by Lobstein, Asch, Haller, and Scarpa, and it has again been described by Bellingeri. I have seen this ganglion twice, and it was present on one side only. It becomes an interesting question in a physiological point of view to know, whether or not the whole of the filaments of the posterior roots of the spinal nerves which join themselves to the accessory, again leave it to form the posterior root of the first cervical. Bellingeri answers this question in the affirmative. "The filaments," he says, "coming from the posterior roots to the accessory are not intermixed, but only approximated, so that they can be separated by slight traction."**

* Scarpa states (opus cit. p. 395.) that in a great number of bodies he examined with a special reference to this point, he found a communication between the accessory and the posterior root of the second cervical only in two instances.

† Circa harum radicularum, quæ pro radicibus posticis primi paris habenter, communicationem illud notamus, quod sæpius accessorium subire, quam eundem intactum relinquere observenter. Opus cit. p. 223.

‡ De Primo Pare Nervorum Medullæ Spinalis, tab. x. fig. 2.; et explicatio, p. 335. Ludwig Scrip. Nevr. Min. Sel. tom. i.

§ Opus cit.

|| Opus cit. p. 80. Monro *secundus* has also given a representation of this communication between the accessory and posterior root of the first cervical. Observations on the Structure and Functions of the Nervous System, tab. x. fig. 2. 1783.

¶ Bischoff states (opus cit. pp. 34. 82.) that in none of the numerous instances in which he dissected the accessory in the lower animals, did he ever observe any filaments of the posterior roots of the spinal nerves join themselves to it.

** Opus cit. p. 81.

And in another place he says, "I believe that the filaments from the posterior roots, which join the accessory, leave it again to proceed to the posterior root of the first cervical."* From this he concludes that the accessory contains no sensiferous filaments. Müller, on the other hand, has adduced some unusual anatomical arrangements in this nerve, which may be regarded as favouring the opinion that it contains sensiferous filaments independant of those which it may receive from the posterior roots of the spinal nerves. He mentions an instance†, which he elsewhere ‡ describes at considerable length, where the posterior root of the first cervical nerve on the right side was not present, and where its place was supplied by two bundles of filaments from the superior part of the spinal accessory. The upper of these bundles, at least, came from the medulla oblongata. Upon the posterior root of the first cervical thus constituted, a ganglion was formed while it was still within the *theca vertebralis*. The upper fibres of the posterior root of the second cervical of this side joined themselves to the accessory, but no nervous filaments were attached to the spinal chord in the usual position of the posterior root of the first cervical. On the left side, the posterior root of the first cervical presented its usual appearance, and was connected to the spinal accessory by some filaments of communication. The filaments of the accessory arising from the medulla oblongata did not, as on the right side, divide themselves into two parts, one of these becoming the substitute of the posterior root of the first cervical: but the whole ran upwards into the accessory nerve.|| Müller also states that Hyrtl has often seen a ganglion upon the accessory nerve opposite the entrance of the vertebral artery into the interior of the cranium; and that Remak showed him an instance of a ganglion upon the spinal accessory at its passage through the foramen lacerum. "I do not, however, affirm," Müller remarks in reasoning from these cases, "that the spinal accessory always contains originally sensiferous filaments, but leave it doubtful." "But in the case," he continues, "where the nervus accessorius forms an intimate connection with the posterior root of the first cervical, or any other nerve, we may suppose an interchange; and this, in the same degree, will render probable the idea of Monro,

* Ibid, p. 79.

† Archiv. für Anat. und Physiol. 1834, p. 12.

‡ Idem opus, 1837, pp. 279—281.

§ Arnold (Bemerkungen über den Bau des Hirns und Rückenmarks, &c., S. 181—183; Zürich, 1838) has published remarks upon this anomalous instance in the origin of the posterior root of the first cervical from the accessory, the object of which is to endeavour to show that Müller had misinterpreted the facts observed. Among other things urged with this view, is the circumstance that the posterior root of the first cervical does not arise usually in the same line with the posterior roots of the other spinal nerves, but somewhat anterior to these. We cannot, however, believe that so experienced and accurate an anatomist as Müller is, could fall into any such mistake as is here insinuated.

that the communication of the spinal accessory with the posterior root of the first, or with any other spinal nerve, will be an equivalent to it for a posterior root." We have already seen that Stilling concludes, on anatomical grounds, that those filaments of the accessory that come from the medulla oblongata contain centripetal filaments.*

The spinal accessory passes through the foramen lacerum posterius in a canal formed by the dura mater, common to it and the vagus, but they are occasionally separated from each other as they enter this canal by a bridle of arachnoid, or of the dura mater. Soemmering has pointed out that the accessory does not perforate the dura mater like the other nerves, but is, as it were, insensibly surrounded by this membrane.†

One or two filaments generally pass between the accessory and the superior ganglion or *ganglion jugulare* of the vagus, as they lie in the foramen lacerum posterius. Hein states that he has more than once distinctly observed, as also Krause has remarked, the superior five, or even six filaments of the root of the accessory approximate very closely to the ganglion jugulare of the vagus, and partly enter into its formation, so that a junction between the vagus and accessory had already taken place in this ganglion, before the filaments of the accessory had been fully collected to form together the trunk of this nerve.‡

As the spinal accessory is passing through the foramen lacerum, it is in close proximity to the posterior surface of the par vagum, and it there divides into its two branches — its *internal* and *external* branches.

The former, or the *internal*, is composed of the filaments forming the upper roots of the nerve (*fig.* 521, 11.), and entirely, or almost entirely, of those coming from the medulla oblongata; and it joins itself to the vagus immediately below the ganglion jugulare of that nerve. The passage of the accessory through the foramen lacerum posterius, its division into two branches, and the distribution of the internal branch as far as it is known, have been already described in the art. PAR VAGUM, vol. iii. pp. 883. and 890, and need not be repeated here.

The *external* branch, composed of those fibres which arise from the spinal chord (*fig.* 521, 12.), proceeds downwards, outwards, and backwards behind the internal jugular vein, in front of the occipital artery, and behind the posterior belly of the digastric and stylo-hyoid muscle, and reaches the inner surface of the sterno-cleido-mastoid muscle at the lower part of its upper third. In continuing its course downwards and outwards, it here generally perforates the sterno-cleido-mastoid; at other times it is only closely connected to it by cellular tissue; but in both cases it gives branches to this muscle. In this part of its course it is strengthened and anastomoses with twigs of the third and second cervical nerves. Continuing its progress downwards and backwards it anastomoses with twigs of the fourth and fifth cervical nerves, and throws itself into the inner surface of the trapezius muscle, among whose fibres it is ultimately lost.

Comparative anatomy of the spinal accessory. — The origin and distribution of this nerve in the mammalia does not essentially differ from what is found in the human species.* Willis states that this nerve is not only present in the mammalia, but also in birds and fishes †; but the existence of it in the two latter divisions of the vertebrata has been subsequently denied by many excellent anatomists. "If an animal," says Mr. Shaw, "does not perform part of the act of respiration by muscles which run from the skull to the chest, no spinal accessory is found. The truth of this observation may be shown by the dissection of any of the larger birds, but the most extraordinary proof is to be found in the neck of the camel. The constitution of the neck of this animal is like that of birds; there being a succession of short muscles along the side of the neck, and attached to the vertebræ, but no long muscle passing from the jaw to the sternum to assist in breathing, as in other quadrupeds." ‡ It appears, however, that in the camel this nerve is present, but it is smaller and differently distributed from what it is in the horse.§ Serres found it in three of the larger birds, Weber in some fishes, and Bischoff has given descriptions and representations of it in several birds, reptiles, and fishes. In these animals the upper part only of this nerve seems to be present, for it does not stretch downwards along the spinal chord to the same extent in them as in the mammalia. The whole of this nerve, in these animals, throws itself into the vagus, while a branch leaves the vagus after it has escaped from the cranium, and taking the place of the external branch of the accessory is distributed to the muscles of the neck in birds and in reptiles, and to the muscles which move the pectoral fin in fishes.|| In the chimpanzee, the spinal accessory, after passing through the foramen lacerum, divides into two branches. The internal runs towards the larynx, into which it penetrates above the os-hyoid. It is placed between the superior laryngeal nerve and stylo-hyoid ligament, and passes behind the internal carotid artery to the superior hyoi-

* Stilling further states (p. 59) that in an anatomical point of view we may regard the upper roots of the accessory forming the *internal branch* of that nerve as being composed of centripetal and centrifugal filaments, exactly like the vagus.

† "Non reliquorum nervorum more, sub arcu duræ membranæ fertur, sed insensili quasi modo a dura membrana obducitur." De Basi Encephali, &c., p. 104, reprinted in Ludwig's Scrip. Nevr. Min. Sel., tom. ii.

‡ Müller's Archiv. 1844, p. 337.

* Dissections of this nerve upon several mammalia are given in detail by Bischoff and Bendz.

† Opus cit. p. 295.

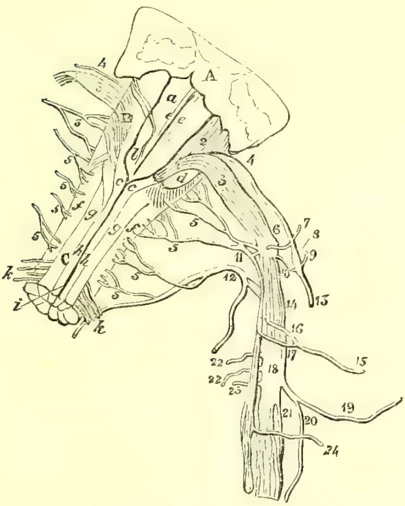
‡ London Medical and Physical Journal, vol. xlix. p. 458, 1823.

§ Vide note by Defermon, at p. 527 of tom. ii. of the Archives Générales de Médecine, 1823.

|| A full account of the comparative anatomy of this nerve is given by Bischoff.

dean region (la région hyoidienne supérieure), where it terminates. The external branch passes downwards below the sterno-cleido-mastoid muscle to reach the trapezius, in which it is chiefly distributed.*

Fig. 521.



From Bendz, reduced one-half.

A, part of cerebellum cut across; B, medulla oblongata; C, spinal chord; *a*, floor of fourth ventricule; *b*, calamus scriptorius; *c c*, posterior pyramidal bodies; *d*, right restiforme body obliquely divided; *f f*, lateral columns of spinal chord; *h h*, posterior columns of spinal chord; *i*, posterior longitudinal fissure; *k k*, posterior roots of spinal nerves; 3 3, roots of vagus nerve; 4 4, roots of glosso-pharyngeal; 5 5 5, roots of nervus accessorius; 6, ganglion of the root of the vagus or superior ganglion; 7, auricular branch of vagus; 8, right ganglion petrosum of glosso-pharyngeal; 9, ramus anastomicus of Jacobson; 10, communicating branch between the superior ganglion of the vagus and the ganglion petrosum; 11, roots of the accessory which form its internal branch; 12, roots of the accessory which form its external branch; 13, glosso-pharyngeal nerve; 14, trunk of the vagus; 15, pharyngeal branch of vagus; 16, filaments of this branch that come from the vagus; 17, filaments of this branch that come from the internal branch of the accessory; 18, ganglion of the trunk of the vagus or inferior ganglion; 19, nervus laryngeus superior; 22 22, communicating branches between the ganglion of the trunk of the vagus and the superior ganglion of the sympathetic; 23, fibres of the internal branch of the accessory which do not enter into the formation of the ganglion of the trunk of the vagus; 24, branch from these fibres which joins itself to the external branch of the superior laryngeal nerve.

Physiology of the accessory.— The peculiar origin and course of this nerve, and particularly its intimate connection with the par vagum, have formed the basis of most of the speculations on its functions since the time of Willis. It was maintained by Willis that this nerve, from its connection with the par vagum, regulates those involuntary movements of the neck and arm caused by the emotions and passions.* Lobstein likewise believed that the spinal accessory joins the vagus for the purpose of connecting itself with the involuntary functions, and he supposed that its paralysis might also affect the movements of the pharynx and larynx.† Others have maintained that it is a nerve of involuntary motion from the particular portion of the spinal chord in which it is implanted. It is, as is well known, one of Sir Charles Bell's respiratory nerves, arising as he supposed from a particular tract in the spinal chord to which he gave the name of respiratory tract, and is therefore, according to this view, a nerve of involuntary motion. Bellingeri believes that the lateral tract of the spinal chord, from which the accessory arises, presides over the instinctive and sympathetic movements, and that it is consequently a nerve of involuntary motion.‡ Arnold §, Scarpa ||, Bischoff ¶, Valentin **, and Longet ††, have maintained that the accessory stands in the same relation to the vagus as the anterior roots of the spinal nerves do to the posterior roots.‡‡ According to this last view, the vagus does not originally possess any motor filaments, but derives them from the spinal accessory. The two first of these authors came to this conclusion on anatomical grounds alone; the three latter, from experiments upon these nerves in living animals, as well as from their anatomy. Bernard has arrived at the conclusion that it is entirely a motor nerve, and that it enables the larynx and pharynx, and muscles of the neck in which it is distributed, to partake in the production of the phenomena of phonation, but that it does not assist in any of the true respiratory movements.§§ Dr. Todd and Mr. Bowman || ||, on the other hand, believe that the internal branch of the accessory is composed of *afferent* nerves, and that the mode of implantation of this nerve in the central organs of the nervous system serves to bring the sentient surface of the lungs and air-passages into immediate relations with the roots of all those nerves which animate the great muscles of respiration, the phrenic, the external thoracic, the cervical plexus, and the motor fibres of the spinal accessory and vagus nerves.

All experimenters agree that the external

* Recherches d'Anatomie Comparée sur le Chimpansé: par W. Vrolik, p. 40. Amsterdam, 1841.

* Opus cit. caput xxviii.

† Ibid. pp. 345, 346.

‡ Ibid. pp. 89, 90.

§ Der Kopftheil des vegativen Nervensystems. Heidelberg, 1831.

|| De Gangliis Nerv. deque Essentia Nervi Intercost. Ann. Univers. di Medicina, 1831.

¶ Nervi Accessorii Willisii Anatomia et Physiologia, 1832.

** De Functionibus Nervorum Cerebralium et Nervi Sympathici, 1839.

†† Anatomie et Physiologie du Système Nerveux, &c., tom. ii., 1842.

‡‡ It appears that this idea had been previously suggested by Görres (Exposition der Physiologie, Coblentz, 1805, as quoted by Müller).

§§ Archives Générales de Médecine, 4ième serie, tom. iv. and tom. v., 1844.

|| || The Physiological Anatomy and Physiology of Man, vol. ii. p. 130.

branch of the spinal accessory is a motor nerve. We found that when it was embraced firmly within the forceps, or tied tightly soon after it had emerged from the foramen lacerum, the animal gave indications of suffering * ; but an experiment of this kind does not enable us to decide whether these sensiferous filaments were originally contained in the accessory, or were derived from the neighbouring nerves. Mr. Shaw has detailed an experiment to show that the movements which it imparts to the sterno-mastoid, and to the trapezius are not voluntary, but respiratory.† In our experiments, and in those subsequently performed by Bernard, these muscles acted in unison with the muscles of respiration after the spinal accessory nerves had been divided.

While all experimenters agree that the external branch of the accessory is chiefly if not entirely composed of motor filaments, they have arrived at discrepant conclusions regarding the functions of the internal branch. Volkmann ‡, Van Kempen §, and Stilling ||, observed no movements of the muscles in which the internal branch of the accessory is distributed, on irritating the roots of this nerve within the cranium; while in those of Bischoff, my own, those of Valentin ¶, Longet **, Hein ††, Morganti ‡‡, and Bernard §§, partly consisting of irritating the roots of the nerve within the cranium after death, and partly, as in those of Bischoff, Longet, Morganti, and Bernard, by lesions of the nerve in living animals, and observing their effects upon the movements of the muscles in which it is distributed, proofs of its being a motor nerve were believed to be obtained. We think that this evidence is sufficiently strong to justify the belief that the internal branch of the accessory does contain *motor* filaments; but it is at the same time highly probable that it is partly composed of *sensiferous* and *afferent* filaments, and if so, its constitution must be similar to the vagus nerve, with which it becomes so closely incorporated. In the art. Par Vagum, sufficient proof has been adduced to satisfy us that the opinion that the spinal accessory furnishes all the motor filaments contained in the trunk of the vagus, is no longer tenable.

(*John Reid.*)

* Edinburgh Medical and Surgical Journal for January, 1838. Valentin states (opus cit. pp. 58. 62.) that he succeeded in increasing the action of the heart by irritating the trunk of the accessory; but Van Kempen (opus cit. p. 65) repeated this experiment without success.

† London Medical and Physical Journal, vol. xlix.

‡ Müller's Archiv. 1840.

§ Essai Experimental sur la Nature Fonctionelle du Nerf Pneumogastrique : Louvain, 1842. In giving the results of Van Kempen's experiments in the art. Par Vagum, foot-note at p. 891, vol. iii. upon the effects of irritating the roots of the vagus within the cranium, I have inadvertently written the palato-glossus muscle *instead of* the palato-pharyngeus or pharyngo-staphylin muscle, as one of the muscles seen to contract in this experiment. I may also here correct another error in the same article: at p. 900, it is stated that Longet believes that the secretion of the gastric juice is greater after section of the vagi than in the sound animal; while in fact he states that it is diminished by section of the vagi, and that this diminution in the secretion may be explained on mechanical grounds.

|| Bischoff's Bericht über die Fortschritte der Physiologie im Jahre 1842, S. 154. In Müller's Archiv. 1843.

¶ Opus supra cit.

** Opus supra cit.

†† Müller's Archiv. 1844.

‡‡ Omodei, Annali Universali di Medicina. Juli, 1843.

§§ Opus supra cit.

SPINAL NERVES (*Les Nerfs rachidiens*, Fr.; *Die Rueckenmarksnerven*, Germ.; *I Nervi Spinali*, Ital.) are thirty-one pairs, and are distributed to the neck, and the upper extremities, the trunk and lower extremities. They are divided into Cervical, Dorsal, Lumbar and Sacral: the first division comprising eight; the second, twelve; the third, five; and the fourth, six. Their general and special characters, and their apparent and absolute connexion with the spinal chord having been already described *, we shall limit the details of this article to their ultimate distribution.

Each spinal nerve, after the union of its roots, divides into an anterior and posterior branch, the former having generally a much more complicated and extensive distribution than the latter. It will be convenient therefore for the purpose of description to enter first into a consideration of the posterior branches.

The posterior branch of the first cervical or sub-occipital nerve is larger than the anterior, and passes internal to and below the vertebral artery, between the arch of the atlas and the occipital bone, to gain the triangular space between the rectus capitis posticus major, the superior and inferior oblique muscles. It is here imbedded in a considerable quantity of fat and dense cellular membrane, and having directed itself from before, backwards, and slightly from below upwards, divides into a series of branches. Two external branches are sent to the two oblique muscles: an internal ascends to the rectus capitis posticus major, and which having supplied this, terminates in the minor: another filament is directed to the anterior aspect of the complexus near to its occipital attachment: and the terminal branch descends, generally perforating the inferior obliquely, and anastomoses with the posterior branch of the second cervical nerve.

The posterior branch of the second cervical nerve emerges from between the lower border of the posterior arch of the atlas, and the lamina of the axis, and is larger than any of the posterior branches of the cervical nerves, and three or four times greater than the anterior branch of the same nerve. It appears at the lower border of the inferior oblique, and having passed a short distance horizontally inwards, winds round this muscle to the anterior aspect of the outer part of the complexus, which it perforates. It inclines outward and upwards between it and the

* Vide Nervous System, vol. iii. p. 657.

trapezius, passes through the latter, and terminates in the skin in the occipital region as the *great occipital nerve*, coursing along with the occipital artery but lying internal to it. Before becoming great occipital, it gives off at the lower border of the inferior oblique a branch to supply this muscle and a superior and inferior anastomotic branch to communicate with the first and third cervical. When passing along the anterior surface of the complexus, numerous branches are given off to this muscle, the trapezius, and splenius. Those for the last muscle are more numerous and larger than the branches, for the two others are directed to the anterior aspect of the muscle, and one or more of them perforate the complexus before reaching it.

The posterior branch of the third cervical is smaller than the second, but larger than the fourth, and situated more externally, emerging from between the transverse processes of the second and third cervical vertebra. It is directed inwards, between the opposed surfaces of the complexus and semispinalis colli towards the median line, and having reached the sides of the spinous processes of the vertebræ, divides into ascending and horizontal cutaneous branches. The *ascending branch*, after a short course, perforates the inner border of the complexus and trapezius, and becomes cutaneous. It continues its course close to the median line, as far as the region of the occiput, the inner and lower part of which it supplies on the internal side of the great occipital nerve.

The *horizontal branch* passes between the ligamentum nuchæ and the inner border of the complexus, and after having perforated the tendon of the trapezius, terminates in external small cutaneous filaments. The nerve prior to division, and at the outer border of the semispinalis colli, communicates by one or more filaments with the posterior branch of the second cervical. From the anastomosis between the communicating branches of the posterior roots of the three first cervical nerves, results an irregular plexus placed between the complexus and outer part of the semispinalis colli, and consequently nearly in a line with the transverse processes of the superior cervical vertebræ. From this *posterior cervical plexus*, numerous branches arise to supply the complexus, splenius, and semispinalis colli. The anastomosis between these posterior branches is, according to Cruveilhier, sometimes deficient.

The posterior root of the fourth cervical nerve varies much as to individual size, but is always smaller than the preceding. It passes downwards and inwards between the complexus and semispinalis colli, and having reached the side of the median line, perforates the tendons of the splenius and trapezius, and becomes cutaneous. In its course it supplies these muscles, and occasionally terminates in the splenius without going to the skin.

The posterior branches of the fifth, sixth, seventh, and eighth cervical nerves have a similar course to the fourth, but decrease in size from above downwards. The fifth and sixth usually pass between the opposed surfaces of the semispinalis colli and complexus, give branches to these muscles, and perforate the inner part of the tendons of the splenius and trapezius, to terminate in the skin at the lower part of the nape of the neck.

The posterior branches of the seventh and eighth cervical nerves pass either through the deep-seated fibres of the semispinalis colli, or between it and the multifidus spinæ, give branches to these two muscles, perforate the tendons of the trapezius and splenius, and terminate by ramifying, the one on the skin above the scapula, the other over the integument, as far as about the spinous process of the third dorsal vertebra. The inter-transversales muscles, cervicalis ascendens, trachelo-mastoid, and transversalis colli, receive numerous small filaments from these nerves almost immediately after their appearance in the neck.

The posterior branches of the dorsal (thoracic) nerves are much smaller than the anterior, and are directed backwards between the ascending costo-transverse ligaments and the sides of the vertebræ. Having reached the outer border of the semispinalis dorsi and multifidus spinæ, they divide into external and internal branches, the latter being muscular and cutaneous in their distribution, the former only muscular in the eight upper. In the first eight the internal branches are larger, in the last four much smaller than the external.

The external or muscular branches of the eight superior pass between the sacro-lumbalis and longissimus dorsi, and give off numerous filaments to supply these muscles, and the levatores costarum; that of the first sending a few filaments to the cervicalis ascendens, trachelo-mastoid, transversalis colli, and scaleni muscles.

The internal branches wind either over the posterior aspect of the semispinalis dorsi, or between it and the multifidus spinæ, and having supplied these muscles with numerous filaments, reach the sides of the spinous processes; here they perforate the rhomboid, latissimus dorsi, and trapezius, the last muscle very obliquely, and become cutaneous, being principally distributed to the skin at the back part of the scapular region.

The external branches of the four inferior pass obliquely downwards and outwards between the sacro-lumbalis and longissimus dorsi, communicating with each other in their course, and at the outer border of the former muscle perforate the tendon of the latissimus dorsi, and become cutaneous, some of the lower filaments being capable of being traced over the glutæal region.

The internal branches of the four inferior are remarkably small, and are lost either in the substance of the multifidus spinæ, or semispinalis dorsi. The cutaneous filaments from the posterior branches of the dorsal nerves given off on the one hand from the internal, and on the other from their external divisions, are situated somewhat in a line with the angles of the ribs, so that they become more external in proportion to their inferior position.

The posterior branches of the lumbar nerves are analogous in their distribution to the four lower dorsal branches, having an external large musculo-cutaneous, and small internal muscular divisions. *The external branches* run along the deep surface of the longissimus dorsi, and at its outer edge perforate the tendon of the latissimus dorsi, and terminate in cutaneous filaments directed over the crest of the ileum to the glutæal region, as far as on a level with the great trochanter. *The internal branches* are lost in the substance of the multifidus spinæ.

The posterior branches of the sacral nerves exist as distinct branches within the spinal canal, and consequently differ from the cervical, dorsal, and lumbar, which become distinct trunks after the main trunks have issued from the spinal or intervertebral foramina. They decrease in size from above downwards, being extremely small, and passing out of the posterior sacral foramina, the fifth coming out between the sacrum and coccyx. They form a minute anastomosis with each other, and with the corresponding branch of the last lumbar, and after having given filaments to the lower part of the erector spinæ, perforate the tendon of that muscle, and are distributed to the skin over the sacrum and coccyx, and immediately around the anus.

The anterior branches of the spinal nerves are much larger than the posterior branches, the two upper cervical forming the only exception. They form intricate plexuses in the neck, the lower part of the spine and sacrum, the nerves given off from those in the first situation being principally intended for the neck and upper extremities ; in the two last for the lower extremities. The intervening series represented by the thoracic nerves, being comparatively simple in their distribution, do not form plexuses.

The Anterior Branches of the Cervical Nerves.

The anterior branch of the first cervical nerve, smaller than the posterior, is directed between the occipital bone and the transverse process of the atlas, passes over the outer edge of the vertebral artery, and appears at the inner side of the rectus capitis lateralis. It then descends, and forms an anastomotic arch with the anterior branch of the second, in front of the transverse process. In its course the rectus capitis lateralis, and rectus capitis anticus minor receive one or more filaments, and it also sends a filament into the canal for the vertebral artery, and which communicates with the trunk of the second cervical between the transverse processes of the atlas and axis. From this anastomotic arch are given off filaments which communicate with the lingual and par vagum and superior cervical ganglion of the sympathetic.

The anterior branch of the second cervical nerve, also much smaller than the posterior passes forwards between the transverse processes of the atlas and the axis, being concealed by the levator anguli scapulæ, splenius, and first inter-transverse muscle, and divides into an ascending branch, passing in front of the transverse process of the atlas, to communicate with the first cervical; and a descending branch.

The descending branch soon subdivides, and gives several filaments of communication with the superior cervical ganglion; one small filament to communicate with the par vagum, another enters the rectus capitis anticus major, and the last concurs to form the cervical plexus.

Anterior branch of the third cervical nerve, larger than the posterior, and twice as large as the preceding, passes between the vertebral artery and inter-transverse muscles, and having given branches to the levator anguli scapulæ and rectus capitis anticus major, communicates above with the descending branch of the second, below with that of the fourth, and in the interval with the superior cervical ganglion, and then again bifurcates to enter into the formation of the cervical plexus.

The anterior branch of the fourth cervical nerve, of the same size as the preceding, communicates above with the third, below with the fifth cervical, in the middle with the superior cervical ganglion, and then enters into the formation of the lower part of the cervical plexus.

The cervical plexus (the deep cervical plexus) is composed of the primary and secondary anastomosing arches of the anterior branches of the four upper cervical nerves. These anastomosing arches are subject to considerable variation, though generally formed by each nerve bifurcating, and, after having communicated with the nerve above and below, again reuniting in a more or less uniform manner prior to giving off their terminal branches. The plexus is situated deeply at the upper anterior and outer part of the neck behind the posterior edge of the sterno-mastoid, in front of the scalenus posticus, external to the rectus capitis anticus major, the carotid artery, jugular vein, and par vagum. It constitutes the chief contents of the posterior superior cervical triangle, and is surrounded by a large quantity of loose cellular membrane, absorbent glands, and fat, and immediately invested with a prolongation of the deep cervical fascia, which renders the dissection of the numerous branches as they immediately proceed from it, difficult. It communicates internally by several delicate filaments with the superior and middle cervical ganglia of the sympathetic; below with the upper part of the brachial plexus, and externally with the spinal accessory, giving several filaments to the muscles with which it is in immediate relation. The branches given off from the cervical plexus may be divided as follows, into

$$\text{Superficial ascending}\ \begin{cases}\text{Superficialis colli.}\\ \text{Auricularis magnus.}\\ \text{Occipitalis minor.}\end{cases}$$

Superficial descending	Supra-clavicular. Supra-acromial.
Deep - - -	Communicating branches. Muscular. Phrenic.

The superficialis colli (superficial cervical nerve) takes its origin from the middle of the plexus in company with, but anterior to the great auricular, the anastomosing branches of the second and third cervical nerves concurring to form it. It emerges from behind the posterior border of the sterno-mastoid about the middle of the neck, and is directed horizontally forwards and inwards, behind the external jugular vein, and between the sterno-mastoid and platysma, and at a variable point divides into two branches, an ascending and descending, the former larger than the latter.

The ascending branch almost immediately divides into numerous filaments, some of which supply the platysma myoides; one or two ascending along the external jugular vein. The greater number are directed upwards and forwards to the upper part of the platysma and digastric muscle, communicate with the deeper seated filaments given off from the portio dura, and becoming cutaneous, supply the skin over the region of the sub-maxillary gland, the chin (communicating with the submental nerve), and the lower part of the cheek; some filaments being directed to the median line to communicate with the corresponding nerve of the opposite side.

The descending branch forms a loop, the concavity of which looks upwards and inwards, perforates the anterior part of the platysma, a little above the middle of the neck, gives off one or two twigs to accompany the anterior jugular vein, and terminates in the skin about the hyoid bone.

The auricularis magnus (the auricular nerve) arises in common with the trunk of the superficial cervical from the anastomosing branches between the second and third cervical. It emerges from behind the posterior border of the sterno-mastoid, above the superficial cervical, and in front of the occipitalis minor. It winds round the edge of the sterno-mastoid, and is directed along it obliquely upwards and inwards to the lower part of the parotid gland on a level with the angle of the jaw, reaches to the anterior border of this muscle, and divides into *a superficial and deep terminal branch.* It gives off before dividing several filaments between the parotid gland and the skin, and others which pass through the substance of the former to terminate in the skin in the malar region, where it communicates with the facial nerve.

The superficial branch courses upwards in the parotid fascia, and on a level with the antitragus divides into several filaments, which are distributed on the one hand to the concave surface of the auricle, particularly the concha; and on the other, to the anterior border of the helix, and the vertical groove in front of it.

The deep branch (anterior mastoid), having perforated the parotid gland, and crossed the auricular branch of the facial, with which it communicates, becomes placed behind the auricle of the ear, ascends along the anterior part of the mastoid process, communicates with the occipitalis minor, and terminates by supplying the skin at the back of the ear, some filaments passing on to its upper border.

The occipitalis minor (mastoid, external occipital) comes from the posterior part of the cervical plexus, taking its origin from the second cervical. It appears at the posterior edge of the sterno-mastoid, behind and above the great auricular. It passes upwards parallel with the great occipital nerve directed by the border of the splenius, which it occasionally perforates, to the occipital region behind the mastoid process; communicates with the great auricular externally, and with the great occipital nerve internally, and ends by terminating in the skin over the parietal bone. There occasionally occurs a small accessory nerve, between the auricularis magnus and occipitalis minor. This is directed along the posterior border of the sterno-mastoid, and is distributed to the skin over the mastoid process.

The supra-clavicular and acromial nerves, form the termination of the cervical plexus, and exist as two primary trunks, which usually about the level of the posterior belly of the omo-hyoid, divide and subdivide into numerous branches, which traverse superficially the posterior inferior triangle of the neck, first passing behind the platysma, then between it and the skin. The internal series (*sternal*) are directed forwards and inwards, over the lower part of the sterno-mastoid, the inner third of the clavicle, and end in the skin over the upper part of the sternum, and upper and inner part of the pectoralis major. The middle filaments (*mammary*) pass over the centre of the clavicle, and are distributed to the skin of the pectoralis major and the mammary gland, and communicate with branches of the intercostal nerves. The posterior (*clavicular*) pass downwards and outwards over the outer third of the clavicle, and ramify in this skin over the anterior and outer part of the deltoid.

The acromial nerves are larger than the clavicular, and are, ordinarily, two in number. They pass obliquely outwards, downwards, and backwards, over the lower part of the superficial aspect of the trapezius, give some filaments to this muscle, which communicate with the spinal accessory nerve, and having reached the acromion, divide into numerous cutaneous branches, which are lost in the skin covering the spine of the scapula, and the outer and back part of the deltoid.

The communicating branches have been already partly described in the consideration of the formation of the plexus; and are formed by different filaments, which are connected with the trunk of the sympathetic, its upper and middle cervical ganglion, as also with the par vagum and lingual. The internal deep branch is represented by the *communicans noni* or *internal descending cervical.* It takes its origin principally from the descending division of the second cervical, and having received a filament from the first cervical, comes down the neck external and posterior to the internal jugular vein. At the middle or lower third of the neck, it describes a curve; the concavity of which looks upwards, and communicates with the descending branch of the lingual (descendens noni), by winding in front of the internal jugular vein. This nerve is subject to considerable variation, bifurcating, occasionally, before communicating with the descendens noni, and giving off now and then one or two delicate filaments to the same muscles, usually supplied by the latter nerve: viz. the sterno-hyoid, sterno-thyroid, and omo-hyoid. The external communicating branches are represented by a rather larger *anastomotic branch*, which communicates at an acute angle with the spinal accessory; and by the *muscular branches*. These accompany the spinal accessory, communicate more or less with it, and are distributed to the trapezius, levator anguli scapulæ, the rhomboideus minor, and upper part of the rhomboideus major.

The phrenic nerve (diaphragmatic, internal respiratory) appears at the lower and anterior part of the fourth cervical nerve of which it appears the continuation. It receives, however, some accessory filaments from the third and fifth cervical, which exist either as single or plexiform twigs, or are occasionally absent. The secondary sources of origin are, in fact, subject to considerable variation. It is directed along the anterior edge of the scalenus anticus, inclining slightly inwards between the subclavian artery and vein, before entering the superior opening of the thorax. It passes behind and outside the carotid artery and jugular vein, and communicates with the fifth, sixth, and, occasionally, with the seventh cervical and pneumogastric nerves, and invariably with the sympathetic. The exact points of communication of these different nerves is by no means determinate; sometimes taking place in the neck; at others, in the upper part of the chest. It crosses the direction of the internal mammary artery, and reaching the anterior mediastinum, glides down in front of the root of the lung between the pericardium and inner aspect of the former, and terminates in the diaphragm. In its course within the chest, it gives several filaments to the remains of the thymus gland; some very minute twigs of communication with the superior cardiac plexus; and receives, occasionally, a very delicate filament of communication, coming down obliquely, from the descendens noni: on reaching the diaphragm, the nerve divides into a series of superior and inferior filaments; the former, long and diverging from each other, enter the upper surface of the muscle, having first passed for some distance between the muscle and the pleura covering it; the latter perforate the muscle, diverge, and run for some distance between the muscle and peritoneum, and enter its under surface.

The right phrenic is shorter and more vertical in direction, and more anterior in its position than the left, being directed in the upper part of the chest, along the vena cava superior. Several of its internal terminal filaments pass behind the vena cava inferior, communicate with the left, and end in the cœliac plexus; a few, however, communicate, also, with some twigs of the pneumogastric.

The left phrenic turns over the apex of the heart; and, besides its general distribution, gives filaments to the crura of the diaphragm, anastomosing filaments to the solar and cœliac plexus, and some communicating branches to the opposite nerve.

The anterior branches of the four inferior cervical and first dorsal nerves are very large, and form, therefore, a remarkable contrast to the four upper cervical, situated above them. They pass through the intervertebral foramina, between the two scaleni; the eighth cervical passing between the foramen common to the last cervical and first dorsal vertebra. Having given off several filaments to communicate with similar filaments from the inferior and middle cervical ganglion, and some small twigs to the scaleni, the different branches unite together, so as to constitute the brachial plexus; the first, communicating above with the fourth cervical, and sending a twig to the phrenic. The union of the different branches takes place in the following manner: — the anterior branches of the fifth and sixth descend obliquely outwards, and, after a course of about one or two inches, unite at an acute angle. Those of the eighth cervical and first dorsal, which are not so oblique in their direction, similarly unite; but a little more internally: this union taking place, occasionally, between the scaleni, either pair of branches almost immediately bifurcating after their union. The trunk of the seventh passes distinct between the two upper and lower branches, as far as the lower border of the clavicle in the upper part of the axilla, and there bifurcates; the upper part of the bifurcation being connected with the lower part of the bifurcation of the first united cord, and the lower with the upper of the last united cord. Secondary bifurcations and anastomoses take place at more or less acute angles, and thus the brachial plexus is constituted.

The brachial plexus (axillary) is situated at the inferior and lateral part of the neck, in the posterior inferior cervical triangle, where it is covered in by a considerable quantity of fat, cellular membrane, and lymphatic glands, which separate it from the external jugular vein. The scalenus anticus bounds it in front and internally; the scalenus posticus in the opposite direction; and in its course from between these muscles to the clavicle, it is crossed by the omo-hyoid muscle, transversalis coli, and humeral vessels, and more superficially, by the supra-clavicular and acromial branches of the cervical plexus. Having passed from beneath the clavicle, it becomes placed between the coracoid process of the scapula and the first digitation of the serratus magnus, and anterior and external to the first rib, and there divides into its terminal branches. In the neck, the plexus is situated superior, posterior, and external to the artery; but as the trunks gradually converge towards the axilla, and the terminal branches again diverge, the artery comes to be bounded by some internally, by others externally. The plexus is broad above, where it represents the base of a triangle, and narrow below at its termination at the upper part of the axilla.

The different branches of the plexus may be divided into those given off above, and those below the clavicle: — the former, for the levator anguli scapula, subclavius, rhomboid, and serratus magnus; the latter, for the upper extremity and its muscles.

Supra-clavicular	Muscular, supra-scapular. Subscapular.
Infra-clavicular	Internal cutaneous. External cutaneous. Median. Ulnar. Musculo-spiral. Circumflex.

Of the muscular branches. *The nerve for the rhomboideus* takes its origin from the anterior branch of the fifth cervical, immediately after it has quitted the intervertebral foramen; but is frequently given off from the cervical plexus: it is, consequently, deeply seated. It either perforates the scalenus porticus or winds round it, to get between it and the levator anguli scapulæ; continues along the costal surface of the latter muscle, and then passes to the same surface of the rhomboideus, as far as its lower part, frequently supplying, in its course, the levator anguli scapulæ, which, in many cases, however, receives filaments from a distinct nerve arising above it, and taking a similar course.

The nerve to the serratus magnus (external respiratory, posterior thoracic), situate at the posterior and upper part of the plexus, arises from it by two delicate roots, which come off from the lower edge of the fifth and sixth cervical, immediately after they have passed the intervertebral foramina. It receives, sometimes, a twig from the seventh. It is directed downwards and outwards, and reaches the thorax between the subscapularis and serratus magnus, passing behind the axillary vessels. It passes along this muscle inferior, to the long thoracic artery, and terminates in its lower part, by numerous filaments.

The nerve for the subclavius is very small, but always present, and is given off from the anterior part of the united trunk of the fifth and sixth cervical. It passes down anterior to the subclavian artery, and enters the middle of the muscle.

The remainder of the muscular branches are very small, and come off from the lower and anterior part of the plexus, being principally derived from the seventh cervical: some pass behind, and others, in front of the axillary artery, enter the axilla, and are distributed to the posterior surfaces of the pectoralis major and minor. They are known under the collective name of *anterior or short thoracic.*

The supra-scapular nerve, larger than the long thoracic, issues from the upper and back part of the plexus, from the united root of the fifth and sixth cervical at their angle of union. It is directed downwards, outwards, and backwards in company with the supra-scapular vessels, passes behind the trapezius and coracoid process to the notch in the upper edge of the scapula, beneath the ligament which converts this notch into a foramen, and which separates it from the supra-scapular vessels. Having reached the supra-spinal fossa, and supplied the supra-spinatus muscle, it winds along the concave external border of the spine, and reaches the infra-spinal fossa, supplying the infra-spinatus. From the inferior filaments one or two twigs can be traced to the teres minor.

The subscapular nerves are intended for the latissimus dorsi, teres major, and subscapularis. That for the first muscle is the largest and longest. It arises from the plexus above, and internal to the circumflex nerve, passes down in the axilla between the subscapularis and serratus magnus, parallel, but posterior to the long thoracic, and terminates by reaching the lower border of the latissimus dorsi, where it enters its substance. It gives off occasionally in its course the branch from the teres major, which usually, however, arises from the plexus below it. This nerve passes downwards and outwards at the subscapularis, and enters the anterior surface of the teres major.

The nerves for the subscapularis are: a small one, generally constant as to its origin arising high up from the same source of origin as the circumflex, passing behind the axillary artery to the upper part of the superficial surface of the subscapularis; the other larger, and frequently derived from the circumflex, to be distributed to the middle of the muscle.

The internal cutaneous, the smallest of the terminal branches of the brachial plexus, and situated most internally, takes its origin principally from the last cervical and first dorsal. It descends, covered in by the brachial aponeurosis, along the inner aspect of the arm, between the median and the ulnar, and concealed above by the axillary artery. Deeply seated in the axilla, in leaving this cavity it inclines slightly forwards and outwards in company with, but anterior to, the basilic vein; and at a variable distance from the elbow joint, generally a little below the middle of the arm, divides into *external and internal cutaneous branches:* both of which perforate the fascia. In this part of its course the internal cutaneous gives off in the axilla a small cutaneous filament, which, having communicated with the second or third intercostal nerve, perforates the fascia, and supplies the skin on the inner part of the arm as far as the internal condyle.

The external terminal branch, the continuation of the trunk in the arm, and the larger of the two, divides into two or three twigs, which pass either in front or behind the median basilic vein, some occasionally passing in front, and some behind. The external filaments course down the anterior and inner part of the fore-arm, following the direction of the median vein, and communicating with branches of the external cutaneous: the internal follows the course of the ulnar vein, communicating with a twig of the ulnar nerve at the lower part of the fore-arm. Both terminate in the integument over the annular ligament.

The internal branch, frequently perforating the fascia lower down than the external, passes behind and then below the median basilic vein, to the inner and back part of the fore-arm, and having communicated a little below the elbow with the accessory internal cutaneous, continues its course, and supplies the integument along the inner and back part of the fore-arm as far as the inner edge of the hand, communicating, in its course, with the innermost filaments of the external branch.

Placed behind and internal to the internal cutaneous nerve, is the *cutaneous nerve of Wrisberg* (the accessory nerve of the internal cutaneous), considerably smaller than it. It arises from the united chord formed by the seventh cervical and first dorsal. It descends along the inner part of the axilla, and communicates with the cutaneous branch of the second intercostal. Coursing down the arm on a plane behind the ulnar and internal to the basilic vein, it perforates the fascia about the lower third, and, becoming cutaneous, divides into anterior filaments, communicating with the internal cutaneous: and posterior, communicating with the internal cutaneous branch of the musculo-spiral.

The external cutaneous (musculo-cutaneous: perforans casserii), larger than the preceding, but smaller than all the other nerves, and most external, is formed by the fifth and sixth cervical. It is directed obliquely downwards and outwards in front of the tendon of the subscapularis to the inner aspect of the coraco-brachialis, perforates this muscle (occasionally, however, passes behind it without perforating), and then becomes situated obliquely between the biceps and brachialis anticus. At a short distance from the elbow it emerges from beneath the outer border of the biceps, and internal to the supinator longus; and at the bend of the elbow, after passing behind the median cephalic vein, bcomes subcutaneous. In this part of its course the external cutaneous nerve gives off a series of muscular branches. Of the two *branches to the coraco-brachialis*, the upper, having perforated it, terminates in the short head of the biceps.

The branches to the biceps unite separately or by a common trunk, and one of them perforates the biceps, and supplies the elbow-joint, being here situated to the outside of the superficial flexor tendons.

The branches for the brachialis anticus are several, and penetrate the muscle by its superficial surface. The continuation of the external cutaneous nerve in the fore-arm is represented by a series of *internal and external cutaneous branches*, which pass down along either side of the radial vein. *The former* near the wrist joins with a branch from the radial nerve, and gives off a filament which perforates the fascia, and accompanies the radial artery to the outer and back part of the wrist, where it supplies small twigs to the front and back of the radio-ulnar articulation. *The latter* gives filaments to the outer and back part of the fore-arm, as far as the wrist.

The median nerve. — The largest of the brachial plexus, and situated between the external cutaneous and the ulnar, arises by two roots, the external common to the median, and the external cutaneous: the internal common to the median, the internal cutaneous, and the ulnar. The fifth, sixth, seventh, and eight cervical and first dorsal nerves consequently concur to form it. Between its two roots is placed the axillary artery. It passes along the inner side of the arm in company with the axillary artery to the bend of the elbow, lying at first to the outside of the vessels, and then a little above the middle of the arm, crosses to its inner side, occasionally, however, continuing all along to its outside. It is slightly overlapped by the inner border of the biceps, having the brachialis anticus to its outside: the latter muscle separates it inferiorly from the ulnar nerve. The upper part of the internal cutaneous nerve runs along its inner side. It sinks into the bend of the elbow behind the semilunar fascia, and in front of the brachialis anticus, passes between the two heads of the pronator radii teres, and is then conducted along the forearm between the flexor digitorum sublimis and profundus to the annular ligament, behind which it passes; and at the lower border of this becomes expanded, and divides into a series of terminal digital branches.

The median nerve gives off no branches during its course along the arm, with the exception of an occasional communicating branch to the musculo-cutaneous below the level of the insertion of the coraco-brachialis; and a branch which is usually found coming off from the anterior part of the trunk a little above the elbow. This is directed along the brachialis anticus to the pronator teres, which it supplies, and sends a few filaments backwards to enter the articulation.

The branches given off in the fore-arm are muscular, interosseous, and cutaneous.

The muscular branches for the lower part of the pronator teres, flexor carpi radialis, palmaris longus, and flexor sublimis, are generally derived from a primary branch, which arises behind the pronator teres a little below the elbow-joint; the lower part of the flexor sublimis, however, receiving several smaller branches from the main trunk. The branches for the flexor longus pollicis and flexor digitorum profundus are given off lower down, there being generally one for the former and two for the latter, the outer part of which only is supplied; the inner part of the muscle being supplied by the ulnar nerve.

The anterior interosseous nerve is the most deeply seated branch of the median, coming off at an acute angle from the trunk, between the origin of the deep-seated muscular branches. It runs vertically downwards in company with, but to the radial side of, the corresponding artery, in front of the interosseous membrane between the flexor digitorum profundus and flexor longus pollicis, giving on either side small filaments to them. Having reached the upper edge of the pronator quadratus, it passes behind that muscle, and terminates either by sending numerous filaments into its posterior surface, or, after having supplied it, perforates the lower aperture of the interosseous membrane, and reaches the back of the carpus.

The palmar cutaneous branch is given off at the lower fourth of the fore-arm, passes forwards from beneath the tendons of the flexor sublimis, and behind the fascia, which it perforates a little above the wrist, and divides into an external filament, which, having communicated with the radial, terminates in the skin of the vola major, and an internal descending over the annular ligament to be lost in the skin of the upper part of the palm.

The terminal digital branches of the median are derived from two primary branches, into which the flattened and expanded nerve divides, after having passed from beneath the annular ligament. These are external and internal, the former supplying the muscles of the thumb, and sending off three digital branches for the thumb and radial side of the index finger, and rather smaller than the latter, which gives off two digital branches for the opposed sides of the index and middle, and the middle and ring finger. The *muscular branch* passes in a slightly curved manner outwards and upwards, and terminates in filaments for the supply of the abductor, opponens and flexor brevis pollicis.

The first digital nerve is directed obliquely downwards and outwards in front of the tendon of the flexor longus pollicis, and near the head of the metacarpal bone, crosses it to its outer side, and continues its course to the extremity of the outer side of the anterior aspect of the first phalanx, where it terminates in dorsal and palmar branches. The dorsal branch winds on to the back of the last phalanx, communicates with the radial, and supplies the skin at the root of the nail; the palmar continues in the original course of the nerve to the skin at the extremity of the thumb.

The second digital nerve, not so oblique in its direction as the first, crosses over the adductor pollicis, gives a filament to it, and is conducted along the inner side of the flexor longus pollicis tendon to the ulnar side of the thumb, sending in its course some filaments backwards to communicate with the dorsal branches of the radial, and terminating in a similar manner to the preceding branch.

The third digital nerve is directed in front, and to the outside of the first lumbrical muscle, gives a filament to it, and reaches to about the middle of the outer side of the proximal phalanx of the index finger, where it divides into dorsal and palmar branches. The dorsal branch passes on to the back of the phalanx, communicates with one of the dorsal cutaneous nerves, to form a nerve which ends in the integuments of the back part of the last phalanx: the palmar branch passes in the original direction of the nerve, and terminates on the outer side of the distal phalanx by again dividing into palmar and dorsal branches, having a similar distribution to the two first nerves.

The fourth digital nerve passes in front of the second interosseous space, gives a filament to the second lumbrical muscle, and about the middle of this space divides into two branches, which are directed along the opposed sides of the middle and index fingers. The *fifth* passes downwards and slightly inwards in front of the third metacarpal space, gives a filament to the third lumbricus, communicates by a delicate filament with the ulnar, and at the middle of this space terminates in two branches for the opposed sides of the middle and ring finger. The termination of the divisions of the fourth and fifth digital nerves, and the branches given off from them, are exactly similar in distribution to the third digital nerve, giving off, like it, on the proximal and distal phalanx, a dorsal branch. Each of the digital nerves, although running along the sides of the fingers, and giving off in their course numerous cutaneous filaments, which are directed towards the axes of the fingers, are not observed to anastomose with each other.

The median nerve in the palm of the hand is situated on a plane anterior to all the flexor tendons, and the trunk before dividing is situated half an inch or more above the level of the superficial palmar arch of arteries which crosses in front of its three internal branches. The accompanying digital arteries are placed somewhat behind, and further from the longitudinal axes of the fingers than the nerves, which, however, in their course send numerous small filaments which wind around them.

The ulnar nerve, somewhat smaller than the median, arises from a trunk common to it, the internal cutaneous and the inner head of the median. The first dorsal and last cervical are consequently principally engaged in forming it. Almost immediately after its origin it is directed slightly inwards and outwards from the median, and behind the internal cutaneous, and at the lower part of the axilla appears deeply seated at the inner aspect of the arm, being directed in front of the triceps extensor muscle. Below the level of the coraco-brachialis it perforates the internal intermuscular septum, and becomes surrounded by several fasciculi, derived from the inner head of the triceps, and passes behind the intermuscular septum to gain the space between the internal condyle and olecranon, being here situated between the two heads of the flexor carpi ulnaris. It now inclines downwards and slightly outwards along the inner part of the coronoid process of the ulna, and then takes a vertical course down the fore-arm, covered over by the flexor carpi ulnaris, and between it and the flexor digitorum profundus. It gradually inclines to the surface, and at the lower third of the fore-arm becomes sub-aponeurotic, and passes from between the flexor carpi ulnaris and inner tendon of the flexor sublimis to the lower part of the anterior surface of the annular ligament, passing along it in a distinct sheath with the artery, in close contact with, and external to, the pisiform and unciform bones, and divides into its terminal branches. In the upper part of the arm the ulnar nerve is in relation with the axillary artery, which is placed between it and the median, nearer however the latter. In the upper part of the fore-arm it is about half an inch or more distant from the artery, but gradually inclines, so as to come in close relation with, but internal to it, in the two lower thirds of the fore-arm, and in the palm of the hand.

The ulnar gives off no branches in the arm; and the first that comes off from it, is when the nerve is placed between the two heads of the flexor carpi ulnaris. There are several small articular filaments which enter the inner part of the joint, and three or four which are distributed to the above muscle. In the upper third of the fore-arm some filaments are again given off to the flexor carpi ulnaris, and others for the supply of the inner half of the flexor digitorum profundus. About the middle a small branch is given off, which, after sending satellite filaments to accompany the ulnar artery, perforates the fascia, and becomes cutaneous to communicate with the internal cutaneous. The largest branch, however, given off from the ulnar, comes away about two inches above the wrist-joint, and is named, its *dorsal branch* (dorsalis carpi ulnaris: internal dorsal nerve). This winds downwards and inwards, and having passed between the tendon of the flexor carpi ulnaris and the bone, perforates the fascia at the back of the fore-arm, and becomes cutaneous a little above the styloid process. It runs then along the inner edge of the carpus; and on the posterior annular ligament terminates in two branches. The *inner branch* passes along the inner and back part of the metacarpal bone, and phalanges of the little finger, supplying the integument as far as its extremity, and sending in its course some small filaments to the abductor minimi digiti. The *outer branch* crosses obliquely the tendon of the extensor minimi digiti, and on the fourth interosseous space sub-divides. The inner sub-division at the extremity of the space bifurcates in order to supply the opposed sides of the little and ring finger. The outer sub-division at the lower extremity of the third interosseous space having communicated with the dorsal branch of the radial, similarly bifurcates for the supply of the integument of the opposed sides of the middle and ring finger. The dorsalis carpi ulnaris, independently of the above branches, sends numerous filaments to the inner and back part of the wrist and hand, and communicates above with the external or posterior cutaneous.

The terminal branches of the ulnar nerve are two in number, *a superficial external, and deep internal.*—The former, after a very short course, divides into two branches, a small internal, and large external. The *internal branch* passes along the ulnar side of the little finger to its extremity, giving filaments in its course to the muscles of the little finger. The *external* passes obliquely across the flexor tendons for the ring finger, gives a filament to the fourth lumbricus, and one of communication with the median, and over the fourth interosseous space at a variable distance from its inferior extremity bifurcates: the divisions of the bifurcation being distributed in a similar manner with the median to the opposed surface of the ring and little finger.

The deep branch is directed backwards and outwards between the abductor minimi digiti, and the flexor brevis to the posterior aspect of the adductor minimi digiti, having first given off on the palm a small branch which sends filaments to these three muscles. It passes downwards in a curved manner, the convexity of the curve looking downwards and inwards, and after a short course passes at an acute angle behind the deep palmar arch of arteries. No branches come off from its concavity. From its convexity and back part and outer termination are derived filaments which supply the two inner lumbricales, the palmar and dorsal interossei, the adductor and flexor brevis pollicis. The deep or perforating interosseous branches can be traced through the two layers of interossei to the skin on the back of the hand, where they communicate with the dorsal cutaneous from the radial and ulnar nerves.

The musculo-spiral nerve (*radial*) slightly larger than the median, arises from the inner and back part of the plexus, and is formed particularly by the three inferior cervical and first dorsal nerves. The trunk from which it arises also gives origin to the circumflex nerve. It passes at first from before backwards, running behind the ulnar, and in front and below the circumflex nerve, and having crossed the conjoined tendons of the teres major, and latissimus dorsi, inclines downwards, backwards and outwards to the posterior surface of the humerus, between it and the long head of the triceps. It continues gradually inclining more outwards, till it reaches the lower third of the arm where it gains the outer aspect of the bone, and here it passes forwards in company with the superior profunda artery, to the anterior and outer aspect of the arm lying internal to the outer head of the triceps which it perforates. It is now directed between the supinator longus and brachialis anticus, and then between the latter and extensor carpi radialis longior, and, having reached the outer and anterior part of the elbow-joint, divides into an anterior and posterior terminal branch.

The branches given off from the musculo-spiral in the arm are numerous, and may be arranged into

Internal	Internal cutaneous. Branch for the internal head of the triceps.
Posterior	Branches for the long head of the triceps. Outer head and anconæus.
External	Cutaneous filaments to the arm. External cutaneous.

The internal cutaneous is the first branch of the musculo-spiral, and continues for some distance deeply seated to the fascia, which it perforates above the middle of the arm, and descends as one or two filaments along the inner and back part of the arm to the elbow, where they communicate with the posterior filaments of the accessory internal cutaneous.

The branch for the internal head of the triceps is the next that is given off. It is a delicate, long nerve, which is directed along the surface of the inner portion of the triceps, running behind the ulnar nerve to within three or four inches of the elbow-joint, when it enters the substance of the muscle.

The branches for the long head of the triceps are numerous, and enter its anterior surface. The superior branch is reflected upwards, and can be traced as far as the axillary origin of the muscle. The inferior or descending branch is the longest, and courses downwards to near the olecranon before entering it.

The branch for the outer head of the triceps and anconæus, given off externally to the branches for the long head, is a long slender nerve. It passes down between the outer and middle head to the outside of the olecranon, supplying the outer head in its course, and terminating in the anconæus by entering at its anterior surface.

The external cutaneous branch is given off below the middle of the arm, as the musculo-spiral is commencing its anterior and outer course. It passes along the outer and back of the arm, and divides into two or three delicate descending filaments which supply the skin, and terminate on the back of the carpus between the posterior branches of the external cutaneous, radial, and dorsalis carpi ulnaris with which they communicate.

The musculo-spiral nerve, before giving off its terminal branches, sends filaments to the muscles between which it passes, viz. the brachialis anticus, supinator longus, and extensor carpi radialis longior.

The anterior terminal branch (*radial nerve*) is the apparent continuation of the musculo-spiral nerve, though smaller than the posterior terminal branch. It passes between the supinator longus and brevis, lying on the latter, and over-lapped by the former, and gradually approaches, in its descent of the fore-arm, the radial artery; so that at the middle it is in close contact with, but external to, the vessel. Having arrived at the lower third of the fore-arm, or a little above, it twists round the deep surface of the tendon of the supinator longus, and appears beneath the fascia on the outer part of the fore-arm, and after a short subaponeurotic course, perforates the fascia, and divides about a couple of inches above the styloid process into *an external large, and internal terminal-branch. The external branch* passes along the outer aspect of the styloid process; and at the proximal part of the wrist sends a communicating loop inwards, to be connected with the cutaneous palmar branch of the median. It then descends on the dorsum of the thumb, and supplies its external border. *The internal branch* crosses obliquely the extensor ossis metacarpi and primi internodii pollicis, and divides into a series of branches which supply the ulnar side of the thumb: both sides of the index finger, and the radial side of the middle. These different branches furnish, in their course along the carpus, several cutaneous filaments, and some small twigs which communicate with the perforating interosseous of the deep branch of the ulnar nerve. The most internal division communicates with the dorsalis carpi ulnaris. The two terminal branches of the radial are subject to much variation: the external being sometimes larger than the internal, and supplying either both sides of the thumb, or both sides of the thumb and the radial side of the index finger. The internal branch occasionally unites with the outer division of the dorsalis carpi ulnaris, and supplies the opposed sides of the middle and ring fingers.

The deep terminal branch (*the posterior interosseous or muscular*) is larger than the anterior, passes downwards and backwards along the inner aspect of the exterior carpi radialis brevis, gives filaments to it, and reaches the surface of the supinator brevis, supplies it, as it passes obliquely downwards, backwards, and inwards through its substance, to emerge at its lower and posterior portion. It here divides into a posterior and anterior series: the former supplying the extensor carpi ulnaris, the communis digitorum, and minimi digiti, entering at their anterior aspect the latter the deep-seated muscles. One of the latter has a somewhat remarkable course; is longer and larger than the rest; and passes along the posterior surface of the extensor ossis metacarpi and primi internodii; and at the lower part of the fore-arm becomes placed between the interosseous ligament and the extensor secundi internodii, and indicator, supplies these muscles with one or two twigs, and is conducted in front of the posterior annular ligament to the back of the carpus, where it assumes a gangliform enlargement, from which numerous filaments radiate for the supply of the ligaments and carpal articulations.

The circumflex nerve (*axillary*) is the most posterior of the terminal branches of the brachial plexus, and is occasionally given off from the musculo-spiral, usually, however, taking its origin from a trunk common to it, and to that nerve, external to which it is situated. After a short course in the axilla, it soon leaves that space by passing downwards and outwards over the upper part of the axillary border of the subscapularis to enter the quadrilateral space above the teres major, below the teres minor, and between the humerus and long head of the triceps to terminate in the deep surface of the deltoid. It gives off in this course branches to the subscapularis and teres minor; that for the latter entering the lower border of the muscle, and prior to dividing into its deltoid branches. — *The cutaneous nerve of the shoulder* passes from behind the posterior border of the deltoid, perforates the fascia, and divides into a series of radiating branches, which supply the skin at the upper and back part of the shoulder. *The deltoid branches* ramify through the substance of the muscle as far as its insertion, and from one of them a filament is given off to the capsular ligament of the shoulder joint.

The anterior branches of the dorsal (intercostal) nerves are twelve in number, the first escaping between the first and second dorsal vertebræ, and the last between the last dorsal and first lumbar. They run more or less parallel to each other without forming plexuses, and are destined to supply the thoracic and abdominal parietes, and the skin about the arm and axilla. They present general and special characters. Each branch runs outwards, from its origin, being separated from the posterior root by the intervention of the anterior costo-transverse ligament, to reach the intercostal space, between the pleura and external layer of the intercostal muscles, and below the intercostal vessels. Having communicated by one or two filaments with the thoracic ganglia of the sympathetic, these nerves are continued between the two layers of the intercostals, to about midway between the spine and the sternum, and here they divide into *cutaneous* and *intercostal* branches. The cutaneous branches perforate, in a very oblique manner, the external layer of intercostals; and, after a short course, forwards and outwards, between them and the serratus magnus, either escape between the digitations of the serratus magnus and external oblique, or perforate their fibres, and divide into anterior and posterior branches. This division takes place sometimes when the trunks of the cutaneous nerves are covered by the serratus and oblique. *The posterior branches* are reflected backwards and upwards, and, after a course of an inch or two between the latissimus dorsi and the skin, terminate in the latter. *The anterior branches* are directed downwards and forwards, or horizontally, and, after a longer course than the posterior branches, terminate, like them, in the skin.

The intercostal branches, though somewhat smaller than the cutaneous, represent the continuation of the anterior branches of the dorsal nerves. They continue in the original course of the latter, below the lower edge of the ribs on the one hand, and the costal cartilages on the other; and near the border of the sternum above, and the linea alba below, perforate the muscular fibres, and become cutaneous. The trunks of the intercostal nerves and their continuation give off numerous filaments to the supply of the intercostal muscles, and several extremely delicate twigs, which frequently pass over the inner aspect of the ribs, to communicate above and below with each other in the intercostal spaces.

The special characters of the intercostal nerves are as follow: —

The first dorsal nerve, ascending in front, and across the neck, of the first rib, to assist in the formation of the brachial plexus, gives off only a small intercostal nerve. This comes away soon after the nerve has left the intervertebral foramen, and is directed along the inner surface of the first rib, to the first intercostal space, without giving off a middle cutaneous branch, and passes along the lower edge of the cartilage to the sternum, by the side of which it perforates the intercostal muscles, and terminates on the skin, at the upper and fore part of the thorax.

The second dorsal nerve crosses obliquely over the second rib, external to its neck, to gain the lower part of the first intercostal space, and again crosses the second rib, to reach the second intercostal space on a level with the middle of the former. *Its cutaneous branch* is of large size, and, supplying the arm with cutaneous branches, is named the *intercosto-humeral*, which perforates the second intercostal space. In traversing the axilla it gives off a branch of communication to the accessory internal cutaneous, and one to communicate with the second intercosto-humeral; the latter united nerve sending filaments to the skin at the upper and anterior part of the arm. Two or three filaments represent the termination of the nerve, cross the lower part of the posterior boundary of the axilla, and terminate in the skin, at the upper and back part of the arm.

The cutaneous branch of the third dorsal (the second intercosto-humeral) is smaller than the second, and passes through the third intercostal space: it divides into an anterior and posterior branch; the former winds upwards, forwards, and inwards, over the lower border of the pectoralis major, to terminate in the mamma and integument; the latter, having communicated with the second intercostal, sends filaments to the axilla, and terminal branches, which are directed to the outer and anterior part of the axilla to supply the skin, at the upper and back part of the arm.

The cutaneous branches of the fourth and fifth dorsal nerves send filaments inwards, to supply the mamma; and filaments backwards, over the superficial surface of the latissimus dorsi, to supply the skin over the anterior and outer part of the scapula. The intercostal nerves of the eighth, ninth, tenth, *and eleventh dorsal nerves* perforate the intercostal spaces of the false ribs, pass through the costal attachments of the diaphragm, to get between the external and internal oblique, as far as the border of the rectus, where they give off small cutaneous branches. Entering the sheath of the rectus, they proceed along the posterior surface of the muscle, and terminate, by giving off some filaments, which ramify in its inner part; and others, which perforate the anterior layer of the sheath, at a variable distance from the linea alba, to supply the skin at the anterior part of the abdomen.

The twelfth dorsal nerve is larger than those that have preceded it, and gives a filament of communication to the anterior branch of the first lumbar nerve. It is directed obliquely downwards and outwards, following the course of the last rib, along the lower border of which it runs, passes behind the anterior layer of the transversalis fascia between it and the quadratus lumborum, and, on a level with the apex of the rib, divides into two branches. *The cutaneous branch*, larger than the abdominal, or continuation of the trunk, perforates, obliquely, the external and internal oblique, gives them some small branches, and then becomes superficial, crosses over the crest of the ilium, and divides into a series of divergent filaments, which lose themselves in the skin of the middle of the glutæal region. *The abdominal branch or continuation of the nerve* passes between the internal oblique and transversalis, supplies these muscles, communicates with the first branch of the lumbar plexus, and terminates in the rectus and pyramidalis, and the skin over them.

The anterior branches of the lumbar nerves are five in number, intervening between the corresponding branches of the dorsal and sacral nerves. They increase in bulk from above downwards, communicate with each other by anastomosing branches, and with the lumbar ganglia by filaments, which come from the latter, or the main trunks. These filaments of communication with the sympathetic, vary in number from two to five, and are in close relation with the convexities of the bodies of the lumbar vertebræ. Several nerves are also given to the supply of the psoas muscle.

The anterior branch of the first lumbar nerve is small, much resembling the anterior branch of the last dorsal. Having quitted the intervertebral foramen, it immediately divides into three branches ; two external and small, viz. : — *the great and small musculo-cutaneous;* the other internal and vertical in direction, and forming *the anastomosing branch with the second.*

The anterior branch of the second lumbar nerve, twice as long and broader than the first, gives off the *genito-crural* and *external cutaneous*, and communicates by a long anastomosing branch with the third.

The anterior branch of the third lumbar nerve, nearly twice as large as the second, is directed downwards and outwards, and gives off, at an acute angle, a large external branch, concurring to form the *anterior crural*, and an internal, the *obturator nerve:* it communicates with the fourth nerve by one branch connected with the main trunk, or by two connected with its two branches.

The anterior branch of the fourth lumbar nerve is somewhat larger than the third. It divides into an external branch connected with the *external* division of the third, to complete *the anterior crural;* and *internal* to assist in the formation of the obturator. Its terminal branch is the anastomosing branch with the fifth, internal to the other two, and vertical in direction.

The anterior branch of the fifth lumbar nerve is the largest of all the series, and terminates in the sacral plexus, and is named the *lumbo-sacral nerve.*

The lumbar or lumbo-abdominal plexus is rather intricate, and formed by the anastomosis of the anterior branches of the five lumbar nerves. Placed upon the sides of the lumbar vertebræ between the transverse processes, and enveloped by the fasciculi of the psoas muscle, it presents, when the latter are dissected away from it, an irregularly triangular appearance ; the apex of the triangle being above, and the base below. In the former situation, the nerves forming it are comparatively delicate, and unite with each nearer the vertebral column than the latter ; it communicates above with the twelfth dorsal nerve, through the medium of the "dorso-lumbar," and below, with the sacral plexus, through the medium of the "lumbo-sacral" nerve. The branches given off from it may be divided into *abdominal* and *crural:* the former being given off from its upper ; the latter, from its inferior or terminal portion.

The abdominal series is represented by the *musculo-cutaneous nerves*, and *the genito-crural. The crural series* by the *external cutaneous, crural*, and *obturator.* The musculo-cutaneous nerves are two in number: the upper being three or four times larger than the lower.

The upper musculo-cutaneous (large abdominal, ilio-hypogastric, ilio-scrotal) is the highest of the branches of the lumbar plexus, taking its origin from the first lumbar nerve. It makes its appearance from behind the psoas muscle about an inch and a half below the last dorsal nerve, runs obliquely downwards and outwards across the quadratus lumborum in the subperitoneal tissue, and about an inch above the crest of the ilium, perforates the tendon of the transversalis, and is continued between it and the internal oblique to the middle of the crest of the ilium, where it divides into two branches, an external and internal. The external passes obliquely between the internal and external oblique, and at the anterior-third of the crest of the ilium, winding on to the glutæal region, divides into an anterior and posterior series of filaments ; the one supplying the integument over the tensor vaginæ femoris, the other that over the anterior part of the glutæus medius. The internal branch, or the continuation of the nerve, after a course of an inch or two, communicates with the small musculo-cutaneous by a loop which usually passes round the internal circumflex ilii vessels. It then divides into an abdominal and scrotal branch. The abdominal runs parallel to the corresponding branch of the last dorsal, generally communicates with it, and passes through the tendons of the internal and external oblique, and is distributed to the skin at the inner part of the groin. The *inguinal*, *pubic, or scrotal* branch runs parallel to Poupart's ligament, in company with, but above, the small external cutaneous, reaches the external ring, and divides into internal terminal branches supplying the skin over the pubis; and external ones supplying the scrotum in the male, and the labia pudendi in the female.

The lower musculo-cutaneous (small musculo-cutaneous—small inguino-cutaneous—small abdominal) is a thin delicate nerve, arising generally from the first lumbar, sometimes from the large musculo-cutaneous, is directed downwards and slightly outwards, along the back part of the psoas, a little in front of the inner border of the quadratus lumborum, crosses the iliacus internus about its upper fourth, and reaches the anterior third of the crest of the ileum. There it is lost by communicating with the large musculo-cutaneous, or, as is generally the case, passes after this communication as a very delicate nerve between the internal oblique and transversalis, supplying the lower part of these muscles, but principally the latter, and parallel to Poupart's ligament, perforates the former muscle at the outer ring, and terminates in a manner similar to the pubic or scrotal branch of the upper musculo-cutaneous, in the scrotum and pubic integument.

The genito-crural nerve (external spermatic — internal inguinal) derived from the second lumbar nerve, and sometimes from the communicating branch between the first and second, passes directly forwards to the anterior part of the psoas muscle, along which it descends vertically to the femoral arch. It lies behind the spermatic vessels, and is crossed by the ureter. Having reached Poupart's ligament, it divides into two branches, an internal or genital, and an external or crural. The genital is directed across the external iliac artery (to which it supplies a few filaments) to the chord, lying below it as far as the internal ring. Prior to entering the inguinal canal the transversalis and internal oblique receive a few reflected branches from it. The nerve then accompanies the chord, crosses the epigastric vessels, supplies the cremaster muscle, runs immediately in front of Gimbernat's ligament, and terminates in the scrotal integument in the male, and labia pudendi in the female, supplying also the integument at the upper and inner part of the thigh, and communicating with the inferior pudendal nerve. The *crural branch* (femoral-cutaneous), having given off several delicate filaments to be distributed to the transversalis and internal oblique, crosses the circumflex ilii vessels, passes underneath Poupart's ligament, a little to the outside of the femoral artery, pierces the fascia immediately below the ligament, and becomes cutaneous, supplying the skin of the thigh at the middle part of its upper third. The division of the genito-crural into its terminal branches is subject to considerable variation, sometimes taking place either immediately after it has emerged from within the psoas, or within the psoas directly after its origin from the plexus. The crural division is at times also extremely small, the external cutaneous then having a more extensive distribution than ordinary.

The external cutaneous (external inguinal) is a branch from the second or from the second and third lumbar, or is occasionally derived from the outer part of the crural nerve. It passes from beneath the outer border of the psoas below its middle, runs across the iliacus towards the space between the two spinous processes of the ilium, lying behind the transversalis fascia. It then passes beneath Poupart's ligament, and divides into an interior and posterior branch. The posterior passes outwards and backwards over the fascia, covering the tensor vaginæ femoris, and supplies the integument at the upper, outer, and back part of the thigh. The extent of distribution of this branch is subject to variation, owing to the circumstance of a corresponding branch being occasionally supplied either by the great musculo-cutaneous, or by the genito crural, when the trunk of the external cutaneous itself comes from the anterior crural. In such instances this branch is small and insignificant, if it exist at all. The anterior branch becoming cutaneous about the upper fifth of the thigh, soon divides into an external and internal, directed downwards, over the fascia covering the anterior and outer part of the rectus muscle. The external division terminates in the integument at the middle third of the outer part of the thigh; the internal at the lower third of the thigh, above and to the outside of the patella.

The *crural nerve* (femoral) is by far the largest branch of the lumbar plexus, and is placed in the substance of the psoas muscle between the external cutaneous, and the obturator, below the level of the former and above that of the latter, from which it diverges at an acute angle. It is formed by the union of the second with the outer branch of the third lumbar nerve, by part of the fourth, and generally by their communicating branch. It is destined to supply the integuments of the front of the thigh, and all the muscles at its anterior and outer portion.

Having emerged from the psoas muscle it is directed forwards and outwards between that muscle and the iliacus to Poupart's ligament, under which it passes, and entering the thigh becomes flattened and expanded, and divides into a series of divergent terminal branches, the trunk occasionally bifurcating before so doing.

The nerve in its course within the pelvis is situated behind the iliac division of the transversalis fascia, external to the iliac artery, and gives off a few branches to the psoas and iliacus. Outside the sheath of the femoral vein and artery it is separated from the latter by the intervention of the psoas muscle.

The terminal branches may be divided into *superficial and deep;* the first consisting of the *internal, and middle cutaneous, and branches to the femoral vessels and pectinæus:* the second of *branches* to the *quadriceps extensor cruris,* and the *cutaneous branch of the inner and* *anterior part of the knee and leg*, viz. *the internal saphænus*.

The internal cutaneous nerve (internal musculo-cutaneous) directed along the inner border of the sartorius muscle, perforates the fascia at the lower third of the leg, occasionally perforating the sartorius before so doing. Having given off several cutaneous branches, which form a connexion with the cutaneous branch of the obturator in this situation, it continues its course towards the lower and inner part of the thigh, having previously communicated with a branch perforating the sartorius, and coming from the internal saphænus. From the thigh it passes along the inner edge of the patella, describing a curve, and sending some terminal filaments from its concavity upwards to unite with the middle cutaneous: others, from its convexity downwards, to communicate with the reflected branch of the saphænus itself, and also its accessory branch.

The accessory saphænus nerve (Cruveilhier) takes its origin from the internal cutaneous; from the anterior crural in company with the latter; or from the trunk of the saphænus itself. It soon divides into a *superficial internal branch*, which passes from within the sheath of the sartorius muscles over the femoral vessels, and adductor longus, and at the junction of about the upper with the middle third of the thigh meets with the internal saphæna vein, which it accompanies as far as the knee-joint, in which situation it communicates with the internal saphænus and cutaneous branch of the obturator. The *external branch*, situated behind the level of the superficial, is directed inwards to the femoral artery, runs along its outer part in close contact with it, and accompanies the vessel in Hunter's canal to its lower extremity. It then quits the artery, is directed in front of the tendon of the adductor magnus, to the upper part of the internal condyle of the femur, where it becomes cutaneous, anastomosing with the internal cutaneous above, with the reflected branch of the saphænus below, and sending cutaneous branches over the inner and middle part of the patella. This branch has been termed by Cruveilhier the *satellite nerve of the femoral* artery: and the superficial branch might with equal propriety be denominated the *satellite nerve of the saphæna vein*. The accessory saphænus is subject to considerable variation, both as to size and origin.

The middle cutaneous nerve perforates the fascia three or four inches below Poupart's ligament, crosses the sartorius muscle, and is directed over the inner part of the rectus to terminate in the cuticle over the front of the patella, anastomosing above with the external cutaneous nerve, and below with the internal cutaneous and accessory saphænus. It frequently divides about the middle of the thigh into two branches, which run parallel with each other. The internal and middle cutaneous nerves not unfrequently perforate the sartorius muscle before becoming cutaneous, the first at the middle, the second at its upper part. They are consequently described also as the *inferior perforating cutaneous*, and the *superior perforating cutaneous*.

The nerve to the femoral vessels is very delicate, and arises internal to the internal cutaneous, sometimes however coming off from the lumbar plexus. It is directed downwards and inwards to the femoral vessels, and divides into a series of filaments, one or two of which are directed through the cribriform fascia to the saphæna vein, along which they pass in a tortuous manner till lost by communicating with the internal branch of the accessory saphænus, about the middle of the thigh. The remainder pass, some behind and some in front of the femoral vessels, and terminate at the lower third of the thigh, by uniting with the external branch of the accessory saphænus.

The branches to the pectinæus are directed inwards behind the femoral vessels, and in their course to this muscle generally send a few filaments to the psoas.

The deep-seated muscular branches arise external to the internal saphænus nerve, and behind the superficial already described: and are from within outwards: Branches for the vastus internus and cruræus: branch for the rectus: and branches for the vastus externus, which are the deepest of all.

The branch for the vastus internus (short saphænus), taking its origin in close contact with the internal saphænus, from which it not unfrequently arises, is directed in company with, but external to it, along with the femoral artery. It separates a little below the middle of the thigh from the vessels, and is directed to the external aspect of the vastus internus, to enter it at its lower one third; but before so doing gives off a *superficial articular branch*, which passes in front of the outer border of Hunter's canal; in this situation occasionally communicating either with the cutaneous branch of the obturator, or the outer branch of the accessory saphænus; crosses through the superficial muscular fibres of the vastus to its aponeurotic termination, which it perforates. It is then reflected forwards, upwards, and outwards, and terminates in two or three filaments, one of which passes behind the ligamentum patella, entering the anterior part of the knee-joint; the others pass in front of the patella, to supply the periosteum and skin over it.

The nerve for the cruræus, shorter than that for the vastus internus, enters the upper and inner part of the muscle, extends as far as its lower part, and gives off filaments to the deep-seated portion of the muscle (the subcruræus) to the periosteum and upper part of the synovial capsule.

The branch for the rectus enters the upper part of its posterior aspect, and divides into a superior branch which passes transversely outwards, and a long vertical branch which passes along its inner side to the lower portion.

The branch for the vastus externus frequently arising in company with that for the rectus, is directed downwards and outwards between that muscle and the cruræus, and, in company with the descending branches of the external circumflex artery, enters its inner aspect by two or three divisions, having previously given off a *superficial articular branch.* This filament, the analogue of the corresponding branch of the vastus internus, creeps beneath the superficial muscular fibres, and near the patella becomes cutaneous, some of the terminal filaments passing behind the outer part of the ligamentum patella, others over the patella, where they are lost in the skin and periosteum.

The saphænus nerve (σαφὴς, manifest), the most internal of the deep-seated branches, and arising behind and external to the middle cutaneous, is the largest branch of the crural. It passes downwards and outwards towards the femoral artery, and, about two or three inches below Poupart's ligament, enters its sheath. The nerve first lies outside and behind the artery; but a little before the vessel enters Hunter's canal it gets anterior to it. During the course of the artery downwards and outwards, to enter the ham, the nerve inclines forwards and inwards, and quits the canal, in company with the anastomotic artery, a little above the level at which the femoral vein and artery pass out. It now follows the course of the sartorius lying behind it, to the inner condyle, and one or two inches above the head of the tibia is placed between that muscle and the gracilis, and gives off, before continuing its course, the *cutaneous tibial* or *reflected branch.* This nerve first runs parallel for a short distance with the tendons of the two muscles, then sweeps downwards, forwards, and slightly upwards over the fascia covering them and their tendinous expansions, and across the spine of the tibia to the skin at the upper and outer part of the leg, about two or three inches below the head of the tibia, communicating above with the internal cutaneous.

The continuation of the nerve, or what may be termed the posterior trunk, inclines slightly backwards from between the tendon of the sartorius and gracilis, and on a level with the knee-joint is a little to the inner and back part of the tendon of the latter. Having received its connection with the cutaneous branch of the obturator, it passes in company with the saphæna vein into the region of the leg, inclining slightly forwards to the back part of the inner border of the tibia. Having supplied the integuments at the upper, inner, and anterior part of the leg, it inclines slightly backwards about its middle, sends filaments to communicate with the continuation of the cutaneous branch of the obturator at the posterior part of the leg. It then again inclines forwards, and terminates about three or four inches above the ankle in two branches. The anterior terminal, the smaller of the two, supplies the skin at the lower sixth of the inner and front part of the leg, and over the front of the ankle joint, a few of the branches entering the articulation. *The posterior* terminal, apparently the continuation of the trunk, supply the integuments over the inner malleolus, upper, inner, and back part of the foot.

The saphænus nerve not unfrequently, in its course in the thigh, in company with the femoral artery, gives off, at a variable height, usually however at the lower fourth of the leg, a small branch corresponding more or less with the distribution of the outer division of the accessory saphænus. The internal saphænus nerve first lies behind the corresponding vein; then in front of it to the middle third of the leg, when it again is placed behind it: an inch or two before it divides into its terminal branches, it is again anterior to it, the latter passing over in front, and the other behind.

The obturator nerve, derived from the third and fourth, and sometimes also from their internal intercommunicating branch, is much smaller than the anterior crural, and rounded. It perforates the inner border of the psoas, along which it is conducted to the pelvis, a little below the level of which it runs to between the external and internal iliac vessels. It then passes obliquely behind the external iliac vein, crossing it at a very acute angle, and reaches the obturator foramen in company with, and above, the obturator artery. It passes through this foramen into the thigh, and terminates by dividing into *superficial* and *deep divergent muscular* branches, situated behind the pectinæus and adductor longus. Soon after its origin a small nerve, the *accessory obturator*, is occasionally observed to proceed from the outer part of the trunk. It passes in company with the femoral vein, anterior and internal to it, beneath the femoral arch, over the horizontal ramus of the pubis, and external to the pectinæus. It is then directed a little inwards, and divides into several branches, some of which enter the joint through the anterior part of the capsular ligament; others supply the posterior surface of the pectinæus, and the remainder, as the continuation of the nerve, terminate by communicating either with the upper part of the trunk of the obdurator itself, or with the branch of the nerve destined for the adductor longus.

The obturator nerve, in passing through the subpubic canal, gives off two or three branches to the obturator externus muscle: one penetrating its upper edge, the others its anterior surface. Some *articular filaments* are also sent off in this direction, and accompany some of the branches of the inferior division of the obturator artery, beneath the transverse ligament to the hip-joint. The relation of these filaments as to size and numbers, however, is not constant, being in the inverse proportion to the size and number of branches given off from the accessory obturator, which is not unfrequently absent.

From the *superficial branch* is given off a long filament internally to the gracilis muscle, which runs for about two inches along the outer surface of the muscle before entering it, another to the posterior surface of the pectinæus, which varies in its size according to whether this muscle be supplied by the accessory obturator or not: and a third to the adductor longus, which also enters its posterior surface.

The most important branch, however, is the *long cutaneous branch* which emerges from behind the lower border of the adductor longus muscle, passes in the fascia behind the internal saphæna vein as far as the knee joint, where it perforates the fascia, and becomes cutaneous at the anterior border of the tendon of the gracilis muscle. In this part of its course, a little below the upper third of the thigh, it communicates either with the internal branch of the *accessory saphœnus*, or with a branch occasionally given off from the saphænus itself, and which accompanies the saphæna vein to the knee joint. It gives off cutaneous branches to the middle of the thigh, forming, with the above nerve, a more or less intricate plexus. Having perforated the fascia on a level with the knee joint, above it, or a little below it, it communicates with the trunk of the internal saphænus (being occasionally only in apposition with it), and internal cutaneous nerve. It terminates by being directed downwards and backwards to above the lower part of the poplitæal region, and continues to give off cutaneous branches, till it is lost in the integument at the inner and back part of the leg to within two or three inches of the ankle: having previously sent filaments of communication to the continuation of the saphænus nerve.

The deep branch of the obturator runs generally behind the adductor brevis, and divides into two branches, one ramifying through the centre of that muscle: the other, *for the supply of the adductor magnus*. From the latter is given off a small articular nerve for the knee joint, which is directed downwards and outwards, towards the attachment of the adductor magnus to the linea aspera, perforates this attachment below the middle of the thigh, and is directed with the poplitæal artery into the ham, winding around the artery, and giving off an internal delicate branch, which enters the knee joint through the ligament of Winslow.

The Anterior Branches of the Sacral Nerves are six in number, and escape from the anterior sacral foramina, decreasing in size from above downwards, and presenting, consequently, characters reverse to what obtain in the corresponding branches of the lumbar nerves. They communicate with the sacral ganglia of the symphathetic, the filaments of communication being usually two between each nerve and the sympathetic.

The first nerve, smaller than the lumbo-sacral nerve, extends more obliquely downwards and outwards, and having passed from the first sacral foramen, unites with it at an acute angle, and communicates with the second nerve.

The second nerve, somewhat smaller than the first, passes more obliquely downwards and outwards from the second anterior sacral foramen, and, having communicated with the third, enters the sacral plexus, sometimes bifurcating previously.

The third nerve, about one-third the size of the second, comes from the third sacral foramen, and passes more horizontally outwards to the sacral plexus, having communicated with the second by a delicate filament sent in front of a portion of the pyriformis intervening between it and the second nerve.

The fourth nerve, considerably smaller than the third, passes from the fourth sacral foramen, communicates above and below with the third and fifth nerve, and terminates in three sets of filaments. One, usually in the form of a single trunk, is directed a little downwards and outwards, between the levator ani and the coccygæus muscle, gives branches to them, and finally becomes cutaneous. This filament in its course generally furnishes a small twig which perforates the great sacro-sciatic ligament, and terminates in the skin over the border of the coccyx. A second, as a single small trunk, passes to enter the sacral plexus. The third series anastomose freely with the hypogastric plexus, and then form of themselves a loose kind of interlacement, from which branches are given off to the rectum sides of the bladder, prostate, and vesiculæ seminales, and the vagina in the female. The levator ani generally receives one or two filaments, a distinct twig entering the middle, the other supplying the anterior part, after ramifying on the prostate.

The fifth passes from the fifth anterior sacral foramen, communicates above and below with the fourth and sixth, and sends a filament which perforates the coccygæus muscle, supplies it, and terminates on the skin to the side of it.

The sixth (anterior branch of the coccygæal nerve) is extremely delicate, passing between the lower cornu of the sacrum, and the upper border of the coccyx, communicates within the bone with the descending branch of the fifth, and terminates by passing along the border of the coccyx in the substance of the sacro-sciatic ligament to become cutaneous. Some filaments are given off from it which supply the coccygæus; others perforate the ligament, and are lost in the substance of the glutæus maximus.

The Sacral Plexus (sciatic) is formed by the lumbo-sacral nerve and the four upper anterior branches of the sacral nerves, principally, however, by the convergence of the three upper: the fourth sacral nerve sending merely a small filament of communication. The branches that contribute to its formation enter it at once, at a more or less acute angle, without any complex subdivision, as usually occurs in other plexuses. It has a well marked triangular figure, the apex being indicated by the line of convergence of the different trunks: the base by the trunks as they issue from the sacral foramina. It rests upon the pyriformis muscle, the internal iliac vessels separating it from the pelvic viscera, being however in immediate relation with a layer of pelvic fascia. Before terminating in the great sciatic nerve, the plexus gives off a series of anterior and posterior branches. Of the former are observed, a nerve for the obturator internus, and the internal pudic: of the latter, the superior glutæal, inferior glutæal, nerves for the pyriformis, gemelli, and quadratus femoris.

The nerve for the obturator internus takes its origin from the upper and outer part of the plexus, being derived from the lumbo-sacral and first sacral. It passes behind the spine of the ischium, and the lesser sacro-sciatic ligament, reenters the pelvis at the lesser sciatic notch, and is distributed by three or four branches within the inner aspect of the muscle.

The internal pudic nerve, arising from the lower part of the plexus, and generally derived from the third and fourth nerves, passes behind the spine of the ischium, internal to the pudic artery, in company with the preceding, and then enters the ischio-rectal fossa, where it divides into a superior and inferior branch.

The superior branch (*the dorsal nerve of the penis*) ascends in company with the internal pudic artery, but above it, between the obturator internus and the levator ani, to pass between the two layers of the triangular ligament: perforating the anterior layer immediately under the pubic arch it gains the dorsum of the penis, in which situation it is placed in the fold of the suspensary ligament, and inclines inwards to the median line. Having given off one or more external branches, which run superficially as long and slender filaments along the upper and outer part of the penis, supply the corpora cavernosa and their integument, and are conducted as far as the prepuce, the nerve continues its forward direction. It passes to the side of the median line, sends numerous filaments to the skin; communicating branches to the nerve of the opposite side; and some to accompany the dorsal vein of the penis; and at the root of the glans penis, penetrates deeply between it and the corpus cavernosum, and terminates by sending numerous filaments throughout its substance.

The inferior branch (Perinæal nerve — superficial perinæal) perforates the obturator fascia at the inner and anterior part of the tuberosity of the ischium, and divides into two branches, an anterior and superior, having previously given off a posterior branch, named by Cruveilhier the *external perinæal*, which passes through the obturator fascia behind the tuberosity of the ischium. It runs in company with, but external to, the anterior branch, superficial to the crus of the penis, and terminates by supplying the lower and anterior part of the scrotum where it gives off filaments on the inside to unite with some from the anterior branch, on the outside to communicate with the long inferior pudendal branch of the lesser sciatic. The anterior branch passes in the interval between the accelerator urinæ and the erector penis, internal to the preceding, and inclines a little forwards and inwards, and ends in a series of long filaments, which communicate laterally with the external perinæal, and send branches to the middle of the lower and anterior part of the skin of the scrotum, some of them being conducted along the skin at the lower aspect of the penis as far as the prepuce. The superior branch soon divides into a series of muscular branches, after having passed above the transversalis perinæi muscle. Some are sent inwards to the external sphincter, levator ani, and accelerator urinæ: others to the erector penis; the termination of the nerve being represented by a small branch, which passes into the substance of the bulbous portion of the urethra.

The pudic nerve not unfrequently gives off *the inferior hæmorrhoidal* (anal), which passes along its inner side, is directed through the obturator fascia to the ischio-rectal space which it traverses to the side of the rectum, and at the upper border of the external sphincter divides into a series of filaments, the anterior of which communicate with the superior branch of the perinæal, and supply the front of the sphincter and the skin over it. The middle and posterior series supply the sides and back part of the sphincter. Some filaments are given off externally, which pass over the great trochanter, and communicate with the long inferior pudendal nerve. The skin about the anus is also freely supplied.

The inferior hæmorrhoidal, when not a branch of the pudic, is given off from the sacral plexus.

The superior glutæal nerve is derived either from the lumbo-sacral nerve only, or from two distinct roots, the one from it and the other from the back part of the first sacral nerve. The former source of origin usually obtains; and in the latter the root from the sacral nerve is not more than half as long as that from the lumbo-sacral. It passes out as a single trunk at the upper and fore part of the border of the sacro-sciatic notch, in front, and above the pyriformis, and divides into *a superior and inferior branch.*

The superior branch takes the course of the superficial trunk of the corresponding artery, courses along the convex border of the glutæus minimus, and supplies principally the upper and back part of the glutæus medius. The *inferior branch* is directed downwards, forwards, and outwards between the two glutæi, and, after a short course, divides into a superficial branch, supplying the upper and anterior part of the glutæus medius; and a deep branch running across the glutæus minimus, supplying it and the medius, and terminating near the great trochanter, by entering the substance of the tensor vaginæ femoris, at the lower, inner, and back part of its sheath.

The inferior glutæal nerve (lesser sciatic) arises from the back part of the sacral plexus by one or more roots. It emerges from the pelvis at the lower and anterior part of the great sacro-sciatic notch, either as a single, or as two, or three, trunks, below the pyriformis, and about a quarter of an inch behind and internal to the great sciatic. It is directed between the tuberosity of the ischium, and the great trochanter, but nearer the former, over the back and inner part of the gemelli, and divides into *muscular and cutaneous branches. The muscular branches* are long and numerous, being destined to supply the glutæus maximus. One series are directed outwards, upwards, and forwards, and, entering its anterior surface, ramify through the substance of the muscle, as far as its upper and anterior part. The other series are directed downwards, backwards, and outwards, over the tuberosity of the ischium, and supply the lower and back part of the muscle.

The inferior glutæal having emerged from beneath the lower border of the glutæus maximus, divides into its two terminal branches, *perinæal cutaneous, and cutaneous branch to the thigh and upper part of the leg. The perinæal cutaneous nerve* is reflected upon the lower border of the glutæus maximus, and describes a curve, the concavity of which looks towards the sacrum. It soon divides into an external large branch, supplying the skin in the glutæal region, and an internal small branch (the long inferior pudendal of Sœmmering), which passes in a curved manner beneath the tuberosity of the ischium. It is then directed beneath the fascia of the upper and inner part of the thigh, running parallel to the ascending ramus of the ischium, and at or near the junction of the latter with the descending ramus of the pubis, perforates the fascia, and becomes cutaneous, supplying the skin in the perinæum ; it anastomoses either with the superficial perinæal, or the external perinæal nerve, and sends terminal branches to supply the inner and outer portions of the scrotum, and the lower part of the skin of the penis.

The cutaneous branch to the back of the thigh and upper part of the leg. — The continuation of the trunk of the inferior glutæal is situated anterior and external to the above-named branches. It passes obliquely over the inner and back part of the biceps muscles, and, a little above the middle of the thigh, ordinarily divides into two branches. The small external branch passes downwards, forwards, and outwards to the upper part of the lower third of the thigh, in which situation it anastomoses with the external cutaneous nerve of the lumbar plexus. The large internal branch runs down a little to the inside of the median line of the thigh to the skin in the poplitæal region, where it divides into external terminal filaments, supplying the skin over the outer and back part of the tibia and fibula, and internal filaments, some of which go to the skin at the inner part of the poplitæal region, others very small, accompanying and surrounding the external saphæna vein, communicate below the middle of the leg with filaments given off from the external saphænus nerve.

The nerve for the pyriformis passes below the level of the superior glutæal nerve, from the middle of the back part of the plexus, generally taking its origin from the third sacral nerve. It is distributed to the anterior surface of the muscle.

The nerves for the gemelli and quadratus femoris pass from the plexus along the lower part of the pyriformis, close to the os innominatum, to the anterior surface of the muscles. That for the quadratus femoris gives off a few branches to the capsular ligament, one of which enters the articulation, and usually sends off the nerve which supplies the inferior gemellus. This nerve comes off frequently from the upper part of the great sciatic.

The great sciatic nerve (the sciatic, ischiatic, femoro-poplitæal), the largest nerve in the body, is formed by the convergence of a branch of the fourth lumbar, the lumbo-sacral, and the three or four upper sacral nerves ; represents the termination of the sacral plexus, and is destined to supply the muscles at the back part of the thigh, and the muscles and integuments of the leg and foot. It escapes from the pelvis, from beneath the lower border of the pyriformis, as a flattened ribbon-shaped nerve, about half an inch broad, soon becomes rounded, and continuing its course from between the great trochanter and tuberosity of the ischium, descends with a slight inclination outwards to the back part of the thigh, a little to the outside of the median line, as far as, or somewhat above, the level of the upper angle of the poplitæal space, where it divides into terminal branches, the peronæal and posterior tibial. This division occasionally takes place within the pelvis, in which instances the outer division passes either between the lower fascicles of the pyriformis or above the muscle, the inner beneath the lower edge of the muscle. In some instances it takes place while the nerve is placed between the trochanter and tuberosity: in others, again, the two trunks are distinct as far as this situation, where they again unite, and subsequently divide in the poplitæal space. In the upper part of its course the nerve is rather deeply seated, being covered over by the glutæus maximus, and having behind and internal to it the branches of the inferior glutæal nerve. At the lower border of the tendon of the glutæus maximus it is crossed by the long head of the biceps, and in the remainder of its course is covered only by the fascia.

It is in relation in front with the two gemelli and obturator internus, the quadratus femoris and adductor magnus. Behind these muscles it passes successively, from above downwards, is in close contact with the superior, and separated from the adductor magnus by a quantity of fat and cellular membrane. The branches given off from the sciatic nerve are muscular and articular. The muscular branches come away above the middle of the thigh, with the occasional exception of that for the short head of the biceps, which arises near the middle.

There are several *branches for the long head of the biceps*, some of which ascend to be distributed to the muscle at its origin; others descend for some distance, and enter its anterior surface.

The nerve for the semi-tendinous is a long delicate filament, which usually passes down to the lower third of the thigh before it enters its surface.

The semi-membranosus generally receives *two or more branches:* and from the lower is not unfrequently derived a branch for the adductor magnus, which also receives a branch from the main trunk.

The articular nerve is usually given about the middle; but as this nerve, in the majority of instances, is derived from the peronæal, it will be described with that nerve.

The peronæal nerve (external poplitæal — external poplitæal-sciatic) is more superficial, and not much more than a third the size of the posterior tibial. It is directed downwards and outwards along the inner edge of the biceps muscle, behind the outer condyle of the femur, the outer head of the gastrocnemius, and the outer and back part of the head of the tibia, to below the head of the fibula, where it divides into four branches, *the anterior tibial,* and *musculo-cutaneous,* the former being larger than the latter.

The peronæal nerve, during this course, gives off *superficial cutaneous branches, and occasionally deep articular:* the former being represented by the *peronæal cutaneous and peronæal saphænus,* the latter *by the superior and inferior external articular.*

The peronæal cutaneous proceeds from the back part of the nerve, generally an inch or two after its commencement. Having passed superficially with the trunk as far as its termination, and having supplied the integuments in its course, it gives branches on the one hand to the integuments immediately on the outside of the external saphænus, and on the other over the upper part of the peronæus longus, the middle terminal filaments extending below the middle of the leg, and communicating with cutaneous branches from the external saphænus.

The peronæal saphænus (communicans fibulæ — communicating saphænus) usually taking its origin above and to the inside of the peronæal cutaneous, is directed downwards and inwards beneath the skin, and communicates with a corresponding branch from the posterior tibial to form the external saphænus. This communication is very variable as to situation, usually taking place below the middle of the leg, where it perforates the fascia, occasionally, however, in the lower part of the poplitæal space in front of the fascia. The nerve now and then runs quite distinct from its corresponding branch, which consequently in these instances entirely constitutes the external saphænus. It is either very small, terminating about the middle of the leg, or divides opposite the lower part of the tendo Achillis into branches which pass over the lower part of the peronæus longus to the skin of the external malleolus, where they communicate with small descending branches from the musculo-cutaneous; and into those which supply the skin at the lower and outer part of the heel, communicating in the interval between the heel and malleolus with branches from the external saphænus.

The deep articular branches are external and internal, the one arising above the other. They are thus described by Mr. Ellis*: — "*The superior external articular nerve,* arising either from the trunk of the sciatic or the external poplitæal in the case of a high division of the sciatic, is a long slender nerve, which descends deeply into the poplitæal space, under cover of the biceps muscle, nearly as low as to the outer condyle, then passes from the space beneath the tendon of the biceps, reaches the superior articular artery, which it accompanies to the front of the joint, and supplies the synovial membrane of the articulation.

The inferior external articular, more frequently a branch of the external poplitæal than of the sciatic, is also a long nerve close to the biceps, and has the same direction as the preceding; but it extends lower down, passing beneath the tendon of the biceps, and below the condyle of the femur, to the artery of the same name, and it divides on the outer side of the articulation into many branches that extend forwards, perforate the capsules, and supply the synovial membrane.

The anterior tibial nerve (interosseous nerve), rather larger than the musculo-cutaneous, passes from beneath the extensor communis digitorum, having previously perforated the deep surface of the peronæus longus, to the interosseous membrane, which it crosses obliquely downwards, forwards, and inwards; and a little below the middle of the leg is placed in front of the corresponding artery. It continues to accompany the vessel beneath the annular ligament, passing first to the inside of it, then to the outside, and again to its inside, while behind the annular ligament it divides into an internal and external terminal branch. The nerve in this course is placed first between the tibialis anticus and extensor communis digitorum; then between the former and the extensor proprius pollicis, and lastly between the extensor pollicis and the extensor communis digitorum. In its course from the leg to the ankle the anterior tibial gives off branches to the different muscles between which it passes; and also one or two delicate satellite filaments to the anterior tibial vessels.

The terminal branches are both rather deeply seated. The *internal deep branch,* the continuation of the trunk in reference to direction, but not to size, being smaller than the external, passes beneath the dorsal artery of the foot and the tendon of the extensor brevis destined for the great toe, gives filaments to supply the inner part of this muscle, and reaches the first interosseous space, sending a few twigs to the first interosseous muscle. At the anterior part of this space it communicates with the musculo-cutaneous, and terminates by dividing into two branches destined for the opposed sides of the first and second toes.

The external deep branch passes obliquely

* Ellis's Demonstrations of Anatomy, p. 675.

outwards beneath the exterior brevis, supplies this muscle, and gives off from its anterior part several delicate filaments, which running close to the tarsus reach the three outer interosseous spaces, and expand in the substance of the interosseous muscles.

The musculo-cutaneous nerve (the external peronæal), commencing its course below and behind the anterior tibial, and running more superficial and external than it, is directed, first obliquely then vertically downwards in the substance of the peronæus longus; it is then situated behind the fascia, and at a variable distance from the ankle, generally at the lower third, perforates the fascia, between the extensor communis, and peronæus tertius. Subcutaneous in the remainder of its extent, it follows the course of the extensor communis, and after running for a greater or less distance parallel to it, divides into an internal and external branch which diverge considerably from each other. This bifurcation is subject to variation, taking place sometimes while the nerve is situated behind the fascia, at others over or very near the annular ligament, and occasionally the two divisions reunite over the annular ligament, and form an irregular oval space between them. While passing deeply between the muscles of the leg this nerve sends two filaments to the peronæus longus, the inferior of which, given off about the upper fourth of the leg, can be traced running in the subtance of the muscle, to within two or three inches of the ankle. The upper part of the peronæus brevis also receives a small branch. Shortly after perforating the fascia, the musculo-cutaneous sends off its *malleolar branches* directed downwards and outwards to the skin over the outer ankle, and anastomosing with cutaneous branches either from the external saphænus, or the termination of the peronæal cutaneous.

The internal terminal branch, passing over the annular ligament giving a few branches to it, and some to communicate with the internal saphænus and anterior tibial, is directed along the inner border of the foot to the inside of the great toe as far as its extremity. *The external branch*, having passed over the annular ligament, divides into three branches which are directed along the three outer interosseous spaces, and near their anterior extremities, each branch again subdivides into two filaments supplying the opposed sides of the four outer toes, the most external filament anastomosing with the external saphænus. Both terminal branches, in their course from the annular ligament to the toes, send off numerous filaments to the skin on the dorsum of the foot. Such is the usual distribution of the musculo-cutaneous nerve; but frequently the outer branch does not supply the inner side of the little toe, and occasionally gives filaments only to the opposed sides of the second and third toes. In these instances an extension of the external saphænus nerves compensates for the deficiency.

The tibial nerve (tibial-sciatic, internal poplitæal) much larger than the peronæal or external poplitæal, is in a direct line with the sciatic nerve. It passes through the centre of the poplitæal space, rather nearer the semimembranous than the biceps, then between the two heads of the gastrocnemius to the lower border of the poplitæus. It perforates the tendinous arch of the solæus, reaches the front of that muscle, and passes down the leg between it on the one hand and the deep-seated muscles on the other. At the lower third of the leg it runs from beneath the inner border of the solæus, and continues its terminal superficial course, anterior and internal to the tendo Achillis, as far as the lower extremity of the tibia, and, on a level with the base of the external malleolus, divides into the internal and external plantar. In the upper part of the poplitæal span, the tibial nerve is superficial and external to the poplitæal vessels in the middle immediately behind, and at the lower part is placed internal to them. This last relation the nerve holds as far as the lower third of the leg, when it crosses the posterior tibial artery again to its outer side. It continues very gradually to separate from the vessel; so that in the interval between the heel and malleolus the nerve is a quarter of an inch nearer the os calcis than the vessel. The branches given off from the tibial are *muscular, articular, and cutaneous.*

The majority of the muscular branches arise from the posterior part of the trunk, and we observe, first, two branches for the two heads of the gastrocnemius entering their anterior surface. The inner branch arises frequently from a trunk common to it and the tibial saphænus; the outer, from a trunk common to it and a large branch for the solæus, which enters, usually, the posterior surface of that muscle. When the outer branch is small, one or two others are given off lower down, to enter its anterior aspect. *The small branch for the plantaris* is derived, in the majority of instances, from the trunk of the tibial; but sometimes from the inferior internal articular nerve.

The nerve for the poplitæus, given off opposite the knee-joint, is directed forwards to the poplitæal vessels, descends external to them, and terminates at the lower border of the muscle by entering its substance.

The nerve to the tibialis posticus comes off from the above, descends along the back of the muscle, gives numerous filaments to it, and terminates by entering below the middle.

The nerve for the flexor communis digitorum and the longus pollicis take their origin together somewhat below the preceding; that for the latter muscle being the larger, and descending to within a short distance of the ankle joint, in company with the fibular artery. The articular branches are three in number, and correspond with the internal and anterior articular branches of the poplitæal artery.

" *The superior internal articular*, very small, arises above the articulation, descends on the outer side of the poplitæal vessels, passes beneath them, and runs with its artery to the front of the femur and inner part of the articulation; this is the least constant of the branches. *The inferior internal articular*, the largest of the nerves to the joint, arises rather above the articulation, descends to it, lying external to the vessels, is then directed inwards, beneath the poplitæal vessels, and meets with the artery of the same name; it now lies on the poplitæus, covered by the fascia, passes beneath the internal lateral ligament, winds round the head of the tibia, perforates the capsule, and supplies the synovial membrane. This branch gives, occasionally, some filaments to the posterior part of the articulation. The last articular branch is the *posterior* or *azygos*, which is given off opposite the joint, or from the inferior internal nerve: it perforates the posterior ligament, and is distributed to the articulation."* We have observed this inferior articular nerve give off, occasionally, muscular filaments to the plantaris, and upper part of the poplitæus.

The cutaneous branch is named the *tibial saphœnus* (external saphænus—communicating saphænus—communicans tibiæ), and takes its origin from the back part of the trunk external to the muscular branches. It inclines a little to the outside of the middle of the poplitæal space, under the fascia, but superficial to the gastrocnemius, along the posterior surface of which it passes till it perforates the fascia at a variable distance from the ankle, and receives the corresponding branch from the peronæal saphænus. It is then directed, under the name of the *external saphœnus*, along the outer part of the tendo Achillis to the outer and back part of the external ankle, where it divides into its terminal branches. In the first part of its course it lies to the inside of the external saphæna vein. Near the lower angle of the poplitæal span it passes in front of the vein to get to its outside, continues external to it as far as about an inch above the outer ankle, and again passes in front of it to its inside.

The tibial saphænus gives off no branch till it becomes external saphænus, and internal and external cutaneous branches arise from it. The internal supply the outer and back part of the leg: and a *superior and inferior calcaneal branch* are generally observed. The superior is directed over the tendo Achillis, supplies the skin at the inner and back part of the heel, and communicates with filaments from the external plantar: the inferior passes along the outer border of the tendo Achillis to the skin at the outer and lower part of the heel. The outer cutaneous run downwards and forwards over the tendon of the peronæus longus, as far as the malleolus externus, communicating above with descending filaments of the peronæal cutaneous; and below with the malleolar filaments of the musculo cutaneous. Independent of these, cutaneous filaments and a few delicate nerves are given off, which accompany the saphæna vein.

The terminal branches are composed of a series of cutaneous branches to the back part of the ankle, heel, and back part of the outer edge of the foot, and a long nerve, the continuation of the trunk directed along the outer edge of the foot to supply the outer margin of the little toe, communicating previously with the musculo-cutaneous.

The termination of the tibial saphænus nerve is subject to considerable variation, both as to size and distribution. It occasionally forms no connection with the peronæal saphænus, and then is very large. When united with the peronæal saphænus, so as to form the external saphænus, its terminal branch not unfrequently divides into two; the one division for the opposed edges of the fourth and fifth toe; the other for the outer edge of the latter. We have observed the saphænus nerve supplying also the opposed edges of the third and fourth toes, whilst the musculo-cutaneous in this instance supplied merely the inner edge of the great toe and the opposed margins of the second and third toes.

The tibial nerve, before dividing into the internal and external plantar, gives off, a little above the ankle, an *internal calcaneal branch*, which in a high division of the nerve comes away from the external plantar. Having supplied the skin at the inner aspect of the heel, it winds beneath the inferior surface of the os calcis, and communicates with the calcaneous branch of the external saphænus.

The internal plantar nerve, larger than the external and analogous to the median nerve in the hand, passes behind the internal malleolus superficial to and distinct from the tendons of the tibialis posticus, and in front of the posterior tibial vessels. It then runs above the abductor pollicis, and is directed in the intermuscular septum, between it and the flexor brevis digitorum. Having perforated this, it appears between the two muscles, and divides into internal and external branch es

The internal branch is smaller than the external, passes from without inwards over the tendon of the long flexor of the toe to the inner side of the metatarsal bone, gives filaments to the abductor pollicis, flexor brevis, and the skin, and terminates at the inner side of the toe, supplying in its course filaments to the articulations, and when it reaches the last phalanx, a small cutaneous branch to the dorsum.

The external branch divides after a course of about an inch or two. The internal division, as it is directed along the first interosseous space, gives off in its course filaments to the first interosseous and lumbricalis, and at the anterior part of this space divides into two twigs for the opposed sides of the great and second toe. The external division, after a very short course, divides into two branches: the *internal* crosses obliquely the second interosseous space, gives filaments to the second lumbricalis, and bifurcates at its anterior extremity for the supply of the opposed sides of the second and third toes: the *external* crosses obliquely to the third interosseous space, and like the preceding divides at its anterior extremity into two twigs for the

* Ellis's Demonstrations of Anatomy, p. 676.

opposed sides of the third and ourth toes, having previously communicated with the external plantar.

These different divisions of the internal plantar nerve give off, in their course, filaments to those portions of the cuticle with which they are in relation; and also small twigs for the metatarso-phalangeal and phalangeal articulations, and muscular branches to the flexor digitorum brevis, over the tendons of which the different divisions of the external portion of the nerve are obliquely and superficially directed.

The external plantar nerve, smaller than the internal, is directed forwards and outwards between the musculus accessorius and flexor digitorum brevis, giving filaments to either, and, having reached the inner border of the abductor minimi digiti, which muscle it supplies, divides into a deep and superficial branch.

The deep branch passes from between the first and second layer of muscles to place itself between the latter and the third, passing in company with the exterual plantar artery. It describes a curve, the concavity of which looks towards the heel and inner malleolus. Filaments are sent off for the two outer lumbricales, for the transversalis pedis, the adductor pollicis, the interossei, and the tarsal and metatarsal articulations.

The superficial branch passes obliquely forwards and outwards between the flexor brevis digitorum and abductor minimi digiti, to both of which it gives filaments, and soon divides into an external and internal branch.

The external branch reaches the outer border of the foot, and terminates at the extremity of the outer aspect of the little toe; giving filaments to the flexor brevis minimi digiti and the articulations. The internal, larger, communicates with the most external division of the internal plantar, and bifurcates at the extremity of the fourth interosseous space, for the supply of the contiguous sides of the fourth and fifth toes. The divisions of the superficial branch of the external plantar nerve, like those of the internal, supply the portions of the integument with which they are in relation, as also the articulations over which they pass.

The internal and external plantar nerves are, in reference to size, directly the reverse of the corresponding arteries: the former giving off seven filaments for the supply of the three inner toes, and half of the fourth; and being analogous in its distribution to the median in the hand: the latter giving off only three filaments for the fifth and half of the fourth toe, and corresponding with the distribution of the termination of the ulnar nerve.

(*Nathaniel Ward.*)

SPLEEN. (*Lien seu Splen*, Lat.; Σπλήν, Gr.; *die Milz*, Germ.; *la Rate*, Fr.) Normal anatomy. The spleen is a single so-called "vascular gland," which is attached to the cardiac extremity of the stomach, and appears to possess some intimate connection with the renovation of the blood.

Situation and form. — The spleen has a roundish elongated form, or almost the shape of half an egg, and lies in the left hypochondriac region. We recognise on it two surfaces, two borders, and two extremities. The *outer surface* (*superficies externa seu convexa*) is completely free and smooth, and often exhibits a more or less deep, long, and oblique incision: it looks outwards, upwards, and backwards; and is in contact with the left costal portion of the diaphragm, corresponding to the tenth and eleventh ribs. The *inner surface* (*superficies interna seu concava*) is directed inwards and forwards; is for the most part slightly concave, and presents, in a prolonged elevation which occupies its middle, a vertical furrow, the fissure for the vessels, or *hilus lienalis*, which contains many holes and depressions, through which pass the nerves and vessels to and from the spleen. This fissure separates the concave surface into an anterior and larger, and a posterior and smaller portion; and it is connected by the broad, but short gastro-splenic omentum (*ligamentum gastro-lienale*), with the fundus of the stomach, to which the remainder of the concave surface is opposed. The *upper extremity* or head of the spleen (*caput lienis*), is the thicker and more obtuse of the two; it occupies the elevated hinder part of the eighth rib, and is connected by a suspensory ligament (*ligamentum phrenico-lienale seu suspensiorum*) with the diaphragm. The *lower extremity* or *cauda lienis*, is thinner and more pointed, and is directed downwards and forwards. The *anterior border* (*margo anterior*) is the thinner and sharper, and is free. The *posterior border* (*margo obtusus*) is thick and rounded, and is in contact with the lumbar portion of the diaphragm, and the anterior surface of the left suprarenal capsule. The spleen is thus least moveable, where it is limited by the diaphragm; but much more so at the site of its attachment to the stomach. But its situation changes with the variable positions of the diaphragm and stomach: thus, on the one hand, it descends and rises in the states of in- and expiration respectively; and, on the other hand, becomes more superficial or deeper, according as the stomach is empty or full.

Varieties of the spleen. — It is not uncommon to find the anterior border of the spleen, presenting one or more separate deep fissures. Also supplementary spleens (*lienculi, seu lienes succenturiati*) are now and then observed: according to Rosenmüller and Giesker, more frequently in the Southern than in the Northern Germans. These are situated in the gastrosplenic ligament, and rarely in the great omentum (Morgagni, Huschke); they are red, of the ordinary splenic structure, and of a size which varies from a linseed to a walnut. They are generally one or two in number, less frequently four or seven, and in a misdeveloped fœtus have even amounted to twenty-three.

The *size and weight* of the spleen experience great variation, not only in different individuals, but even in one and the same person:

of this more will be said hereafter. On an average, its length is from 4 to $5\frac{1}{2}$ inches * ; its thickness from 1 to $1\frac{1}{2}$ inches ; and its breadth, from the anterior to the posterior border, 3 to 4 inches. According to Krause, its cubic contents range between $9\frac{3}{4}$ and 15 inches, with an average of 12. Its absolute weight varies from 6 to 15 oz., according to Soemmering ; from $7\frac{1}{2}$ to $10\frac{1}{2}$, according to Krause ; and it has a medium of about 8 oz. According to J. Reid †, between the twentieth and sixtieth years, it ranges from 6 to 10 oz. in the male, and from 3 oz. $13\frac{1}{2}$ dr. to 9 oz. 10 dr. in the female. Krause also states, that its specific gravity varies from 1.0579 to 1.0625, with an average of 1.0606.

The *consistence* of the spleen is not very great : its parenchyma is soft and doughy, readily yielding to the pressure of the finger. It is not unfrequently torn by mechanical injury during life ; indeed, more easily than any other glandular organ, especially if it be over-distended with blood at the time; but, under the opposite circumstances, it is much less disposed to give way. The colour of the spleen is bluish red, during life greyish violet, and the parenchyma is of a dark dusky red.

Structure. — In the spleen we first distinguish the *coverings* or *involucra*, and the *parenchyma* or proper spleen-substance. The first consists of the serous and the fibrous membrane. The latter is composed of a framework of reticulated fibres firmly connected together, constituting the so-called trabecular tissue (*trabeculæ lienis*) ; and, beside this, of the red spleen-substance, the splenic corpuscles, and vessels and nerves, together with sheaths which arise from the fibrous coat.

1. The *serous membrane* (*tunica serosa*) is a part of the peritoneum. It accurately covers the outer surface of the spleen as a smooth membrane, with the exception of its hilus only, where it takes the form of two folds which convey the vessels of the organ, constituting the gastro-splenic ligament, and passing off to the stomach, where they become continuous with its serous covering. When the ligament uniting the spleen to the diaphragm exists, the membrane is similarly continuous with the peritoneum covering this muscle. The serous membrane is a thin, moderately strong, whitish membrane, which is intimately connected with the fibrous coat ; although in particular places, and especially after previous maceration, the two may be separated from each other. In respect of its microscopical structure, it scarcely differs at all from other parts of the visceral layer of the peritoneum; thus it consists of an outer and single layer of polygonal pavement epithelium, and of an inner layer of white fibrous tissue, in which meshes of fine fibre of yellow tissue are present in no very considerable quantity.

In mammalia, *e. g.* in the sheep, ox, &c., as was remarked by Malpighi, the serous membrane is easily separated entire. But in man this is not the case, and hence Haller and others have supposed that only one membrane is present. But microscopical research proves the opinion to be erroneous ; and pathological anatomy confirms this statement, by showing that the outer part of the coat of the spleen shares in the diseases of the peritoneum. In animals numerous vessels are seen in the serous membrane, and a very dense network of stronger and thicker fibres of yellow tissue is present.

2. The *fibrous coat* (*tunica fibrosa, albuginea, sive propria*) is in man a moderately delicate semi-transparent, but firm, membrane, which encloses the parenchyma of the spleen on every side, so as to include it in a kind of sac. Its outer surface is even, and in man is intimately united with the serous covering, with the single exception of the hilus, where the two membranes diverge, and are separated from each other by vessels, nerves, and a loose areolar tissue. The inner surface bounds the parenchyma of the organ, and, with the exception of very numerous solid processes which come off from it, is limited by the trabecular tissue. At the hilus of the spleen it sinks into the interior of the organ in the shape of tubes (*vaginæ vasorum*), which ensheath the entering and emerging vessels, and are continued on these throughout the whole parenchyma. The fibrous coat, in the human subject, is composed of white fibrous tissue, mixed with elastic or yellow fibres. The former of these, as in other fibrous membranes, consists of bands, which take a parallel course, but do not form distinct bundles ; and the latter are united in a very dense and irregular network. Duvernoy and Stukely have described muscular fibres in this tunic ; but, according to my researches, they certainly are not present in the human subject, although I have found them existing in some of the mammalia, and most visibly in the dog and pig. They are unstriped muscles, the elements of which, the elongated cells or "fibre cells" (*fig.* 522.) which I have described *, are deposited in considerable quantity amongst the elastic network and white fibrous tissue previously mentioned.

Fig. 522.

Muscular fibre-cell from the tunica propria of the spleen of the Dog, magnified 350 diameters. *a*, nucleus of the same.

In addition to these two animals I have also found the muscular structure in the cat, the ass, and the Dicotyles

* In this and the following measurements the German inch and line have been retained.

† London and Edinburgh Monthly Journal, April, 1843.

* Zeitschrift für wissenschaftliche Zoologie, von v. Siebold und Kölliker, Leipzig, bei Engelmann, Jahrgang, 1848, Heft 1.

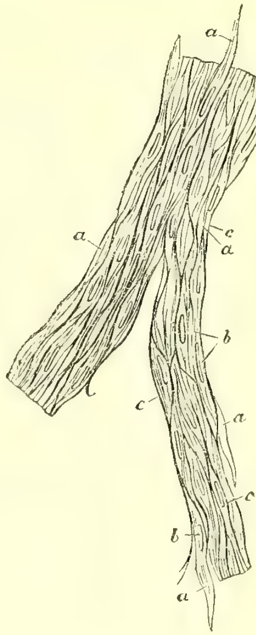
torquatus, while it was absent in the rabbit, horse, ox, hedgehog, guineapig, and bat. The elastic fibres of this tunic are for the most part much stronger than in man.

Their peculiar vessels and nerves I have never witnessed.

3. The *trabecular tissue*, (*trabeculæ lienis*, *balks*, or *joists* of the spleen), consists of white, shining, flat or cylindrical fibres, which arise in great numbers from the inner surface of the fibrous coat; and, in smaller quantity, from the exterior surface of the sheaths of the vessels. These are so connected with similar fibres in the interior of the spleen as to constitute a network which extends throughout the whole organ. Between the fibres of this net exist a great number of spaces which are connected with each other, and are occupied by the red spleen-substance and splenic corpuscles ; and which, although very irregular in respect of their form, and, as regards their size, of the most variable dimensions, have yet a considerable resemblance to each other. The older anatomists regarded these spaces as regular and uniform cavities provided with a special membrane. But this last structure nowhere exists, as may be verified in a spleen in which, after short maceration, the pulp has been removed from these spaces by washing. Such a preparation will also afford the best means of studying the mode of connection of the fibres, and in this manner it may be seen that, although they are of very different diameters, yet the finer fibres are not everywhere given off from the thicker ones. This is especially shown by the fact, that fibres of the most different diameters are intimately connected together at all points. Where four, five, or more of these joists meet, there generally occurs a knot of a flattened cylindrical form, which is not unlike that of a nerve-ganglion. Such knots are more frequently found towards the outer surface of the organ, since the cross-beams are more numerous here than in the interior. In this latter part, namely in the neighbourhood of the great vessels, the numerous ramifications of these tubes themselves serve as points of support to the pulp, and consequently render the joists less necessary.

The structure of the trabecular tissue of the human spleen completely corresponds with that of the fibrous tunic, since it consists of white fibrous tissue and the yellow fibres. The former of these two structures exhibits parallel fibrillæ, which run without exception in the direction of the long axis of the partition or joist, and rarely unite into individual bundles. The latter consists of somewhat finer and stronger yellow fibres, which anastomose with each other ; their maximum diameter is 1,1000th of a line: the greater number of them lie between the bundles of white fibrous tissue, and are easily recognised by their irregular course and manifold curves. Many anatomists, with Malpighi, had spoken of muscular fibres in the partitions of the spleen, although none had succeeded in demonstrating them, either with the scalpel or microscope, or chemically. But in 1846 I discovered them with the aid of the microscope, in the spleen of the pig.* Here they exist both in the finest and largest of the partitions, but they are not isolated, being connected with the finer reticulations of the yellow fibres (*fig.* 523.). In the larger partitions which are

Fig. 523.



A trabecula from the Spleen of the Pig, magnified 350 *diameters, and treated with acetic acid.*

a, muscular fibre-cells with a projecting extremity or not isolated; *b*, nuclei of the same; *c*, elastic fibres.

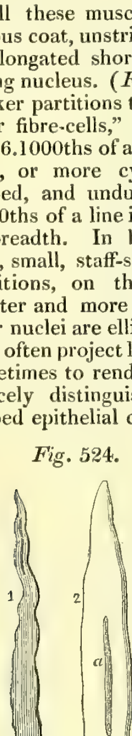
visible to the naked eye, the muscular and elastic fibres are present in pretty nearly equal quantities, consequently these parts are to be regarded as alike elastic and contractile. But in the smallest and microscopic cross-beams the muscular fibres predominate, and often they appear to be even unmixed with elastic fibres. In these parts the quantity of white fibrous tissue is still smaller than that of the yellow ; indeed, in this animal it is but very sparingly present in the larger partitions. The direction of the fibres above-named is always longitudinal or parallel to the long axis of the joist, never transverse. In similar extent and quantity, and with a like connection to the elastic tissue, I have found muscular fibre in the dog, the ass, the cat, the Dicotyles torquatus, the sheep, rabbit, horse, hedgehog, guineapig, and bat. In the ox, on the contrary, it exists only in the finer and microscopic partitions, where it is present in very considerable quantity and in remarkable distinctness. The remainder of the trabecular tissue consists only of yellow fibre in union

* Mittheilungen der naturforschenden Gesell schaft in Zurich, 1847, S. 120.

with some white fibrous tissue. As to the lower vertebrata, I have examined a great number of them with respect to this muscular structure, and have found that the smallness of the spleen in many of them offers a great obstacle to observation; yet I believe I have verified that the spleens of the pigeon, sparrow, blindworm, tench (*tinca chrysitis*), and trout, contain muscular fibres. So, also, my friend Professor Ecker, of Basle, has orally communicated to me that he has found very distinct muscular fibre in the spleens of the ray and shark.

All these muscles are, like those of the fibrous coat, unstriped; their elements consist of elongated shortish fibres, each possessing a long nucleus. (*Fig.* 523. *a*, *Fig.* 524.) In the thicker partitions there are what I call "muscular fibre-cells," either stiff, pale, flat, from 4 to 6.1000ths of a line broad, and 2 to 3.100ths long, or more cylindrical, darker, spindle-shaped, and undulating, varying from 2 to 5.100ths of a line in length, and 3 to 4.1000ths in breadth. In both cases they have long, neat, small, staff-shaped, nuclei. In the finer partitions, on the contrary, appear many shorter and more spindle-shaped fibre-cells; their nuclei are elliptical or even spherical, and they often project laterally from the fibres, so as sometimes to render these muscular elements scarcely distinguishable from the spindle-shaped epithelial cells of the splenic arteries.

Fig. 524.



Muscular fibre-cells from the trabeculæ of the Pig, magnified 350 *diameters.*

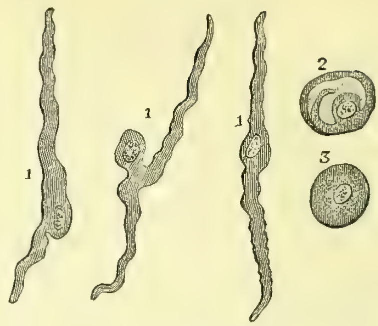
1, without acetic acid; 2, with acetic acid; *a*, nucleus.

The muscular elements just described are seen in the best and plainest manner in the pig and dog; but they are also readily verified in the horse, ox, ass, sheep, and cat, in all of which they may frequently be isolated. In the other mammals previously named, and in the rest of the vertebrata, they are less easily recognised, and are scarcely susceptible of isolation; but they can always be partially uncovered, and in any case may be demonstrated by the application of acetic acid, which displays their characteristic nuclei.

As regards the human subject, I find that in the partitions which are visible by the naked eye, no trace of unstriped muscular fibre is present; and they probably consist entirely of yellow and white fibrous tissue. In the finer partitions, on the contrary, elements occur to which one may perchance ascribe a muscular character. They are the same short fibres of a peculiar kind (*fig.* 525. 1.), which Günsburg* has

* Pathologische Gewebelehre, Band. i. S. 81.

Fig. 525.



Peculiar structures from the human spleen, magnified 350 *diameters.*

1, spindle-shaped fibres with a nucleus; 2, a cell, which contains such a fibre; 3, a similar cell, without a fibre.

erroneously regarded as epithelial cells of the splenic veins; otherwise they have hitherto remained altogether unnoticed. They are characterised by their roundish or elongated oval nucleus, which is laterally disposed, and often occupies a pedunculated process; by their homogeneous texture; by their easy undulatory or serpentine outline; and, finally, by their size, which offers a breadth of 15 to 25-1000ths, and a length of 2 to 3-100ths of a line. The round nuclei of these fibre-cells, even at first sight, somewhat militate against their muscular import; but it must be recollected, that in the mammals named it has been previously stated that the muscular fibre-cells, which occur in the smallest partitions, deviate considerably from the characteristic fibres, and greatly resemble the structures now described in men. On this account, and from the further fact, that the above mentioned human fibre-cells, in moderately fresh spleens, seem to occupy the smallest partitions, just as the muscular fibres in animals; while in later periods after death, or in decomposed spleens, they can only be found isolated, with the parenchyma cells, in the red pulp of the spleen, I formerly considered it not too hazardous to regard them as muscular fibre-cells. But more recently I have made some observations which have again thrown me into complete uncertainty in respect of the import of these questionable structures. Thus I believe myself to have verified, that these fibres occur in the human subject rolled together in a kind of spherical cell (*fig.* 525. 2,) of 5 to 7-1000ths of a line in diameter; and that, on tearing up this structure they become free, and extend themselves. But, since this fact in no way harmonizes with the nature of muscular fibre-cells, and is besides altogether obscure and incomprehensible to me, I hesitate to express at once an opinion concerning the above-mentioned structures in the human spleen, but am desirous of calling the attention of inquirers to this peculiar arrangement, which, on account of its constancy and frequency, is very interesting

4. The *splenic corpuscles* or *Malpighian corpuscles of the spleen* (*vesiculæ seu glandulæ lienis, s. corpuscula Malpighii*) are whitish spherical corpuscles, which are imbedded in the red spleen substance of certain animals, and are connected with the smallest arteries. In the dead bodies of men, in the state in which they are generally subjected to examination in hospitals, these corpuscles are very seldom seen. On this account, some of the earlier observers, as Rudolphi, Heusinger, Andral, and others, and more recently Gluge * and Oesterlen †, have regarded them as not constant structures, or even as products of disease; or have considered them as J. Muller formerly did ‡, to be altogether distinct from the splenic corpuscles of the Ruminantia. But this view is erroneous, and since Giesker §, Krause ‖, and Bischoff ¶, who described the splenic corpuscles of the human subject, and showed their correspondence with those of the mammalia; and since the revocation by Müller of his earlier opinion **, all observers are tolerably agreed, that although the corpuscles in question are often deficient in the human subject, yet they are not the less to be regarded as normal structures, which are invariably present in the healthy subject.

The frequent deficiency of the splenic corpuscles is explained by many circumstances. Most of the observations of them concern human individuals, in whom a long abstinence from food has preceded death. In such cases, as Henle has well remarked ††, the apparent absence of the corpuscles is easily explicable, since their size is notoriously regulated by the quantity of ingesta. So, also, great number of the human spleens which come under our notice are diseased; either softened, distended with blood, and soaked through with extravasations, or enlarged, hardened, atrophied, or already half decomposed and putrified. Finally, the human spleen corpuscles are very delicate, and easily destroyed. As to the frequency of their occurrence in diseased subjects, we are supplied with accurate data by v. Hessling, who has given the results of 960 dissections. Of the whole number just mentioned, Malpighian corpuscles were only present in 116, or in about every eighth individual. He also adds the following numerical statement respecting the different ages of life. In the first and second year of life the corpuscles were present in every second subject; from the second to the tenth year, in every third subject; from the tenth to the fortieth year, in every sixteenth; from the fortieth year to old age, in every thirty-second. These numbers are in general correct, and are readily explicable when we recollect that diseases of the spleen are more numerous as age advances. But the results of my own observations coincide with those of Oesterlen, in representing the number of cases in which corpuscles are detected as greater than that above mentioned. This difference may be ascribed to the difficulties which often prevent the recognition of the dwindled spleen corpuscles; thus in many cases where the first view has afforded no signs of their presence, the application of soda, or the washing of the pulp, has brought them into view.

On the other hand, it is absolutely certain that, in many spleens, they disappear without leaving any traces, and cannot be made visible by any method of treatment. In the bodies of healthy individuals which are examined while fresh, they may always be detected; at least, there are very numerous observations extant in which they have been found after accidental deaths, executions, suicides, &c.; and to these cases I myself am enabled to add two. So, also, I have found them in a great majority of the bodies of children which I have examined; and here they are both very distinct and numerous, so as not to offer any visible difference, in these respects, from those of the Ruminantia.

The size of the Malpighian corpuscles experiences many variations both in men and animals, even apart from the effects of disease: they measure from one-tenth to one-third of a line; on an average, about one-sixth. Their size has hitherto been somewhat too highly estimated; and chiefly on this account, that sufficient preliminary care has not been taken to isolate them from the surrounding parts: when this is done it will be found, that they are not so large as appears from viewing them on a section of the spleen; and that, in many cases, they measure less than the given bulk. The fluctuations in their size depend not merely upon the differences of individuals, but obtain in one and the same animal: in this latter case, they appear mainly to be regulated by the condition of the chylopoietic viscera; although accurate data, as to these points in the human subject, are altogether deficient.

It is also possible, as Oesterlen has supposed, that these corpuscles experience a certain course of development; and that, in many cases, the very small corpuscles are very young and undeveloped ones: but, hitherto, I have not been able to observe facts importing the certain existence of a continual development of the Malpighian corpuscles in the adult animal; nevertheless, I cannot avoid mentioning that, like Oesterlen, I have seen in the spleens of animals little heaps (from 2 to 4-100ths line in size) of cells, which have no distinct cell walls, and which, possibly, have some relation to the formation of the splenic corpuscles. It seems quite certain that the spleen corpuscles are not developed from separate cells of the spleen pulp; although this view has lately been brought forward in a singular manner by Heinrich.*

* Häser's Archiv. für die gesammte Medicin, 1841, SS. 83. 88.

† Beitrage zur Physiologie des gesunden und kranken Organismus, Jena, 1843, S. 48.

‡ Müller's Archiv, 1824, S. 80.

§ Splenologie, S. 159.

‖ Anatomie, Band. i. S. 520.

¶ Müller's Archiv, 1838, S. 500.

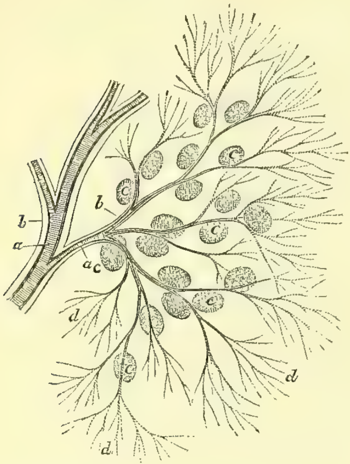
** Physiologie, Aufl. 4. Band. i. S. 466.

†† Algemeine Anatomie, S. 1000.

* Die Krankheiten der Milz, 1847, S. 15.

The *Malpighian corpuscles* are imbedded in the red spleen substance, and, with the exception of one point, where they are attached to arterial twigs, they are everywhere surrounded by this substance. They are con-

Fig. 526.

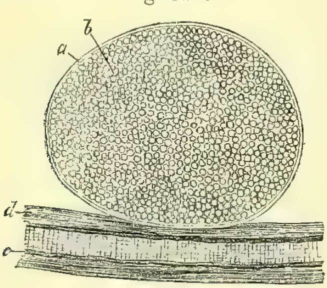


A small arterial trunk with Malpighian corpuscles, on a somewhat larger artery. From the spleen of the Pig. Magnified 10 *diameters.*

a, the artery; *b*, the sheath of the same; *c*, Malpighian corpuscles; *d*, pencils or tufts of arteries.

nected to the small arteries and their twigs by short peduncles, like the berries of a bunch of grapes; and, in such wise, that a small arterial trunk of from 2 to 4-100ths line, with its ramifications, supports 5 to 10 corpuscles. (*Fig.* 526.) The peduncles of the corpuscles are almost always small arteries, which pass to be distributed to them; but in less frequent instances, they are constituted by short processes of the arterial sheaths, which are continuous with the membranous wall of the corpuscle. In this manner the majority of the

Fig. 527.

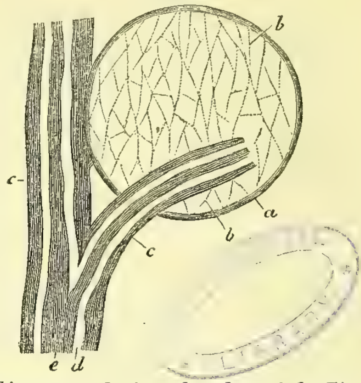


A Malpighian corpuscle from the spleen of the Ox in connection with a small artery, magnified 150 *diameters.*

a, wall of the Malpighian corpuscle; *b*, contents of the same; *c*, coat of the artery; *d*, sheath of the same.

corpuscles are essentially devoid of a peduncle, and sit immediately on the arteries at their points of bifurcation, or at their sides. (*Figs.* 527, 258.) This relation, which also obtains

Fig. 528.



Malpighian corpuscle from the spleen of the Pig in connection with an artery from which a branch passes to the corpuscle. Treated with soda, and magnified 250 *diameters.*

a, wall of the corpuscle; *b*, elastic fibres in the same; *c*, sheath of the artery; *d*, dissolved middle tunic of the artery; *e*, elastic inner coat.

in animals, formerly appeared to J. Müller as indicating the fact that the splenic corpuscles were hollow excrescences of the vessel-walls, or were imbedded in these latter. But if by this be understood, what Müller's plates and description imply, that the sheaths of the vessels, in their whole thickness, with all their elements, are continued to form the corpuscles, then it is certainly incorrect: for in some animals I have seen that, from the rich network of elastic fibres and muscular structure of these sheaths, little or nothing passes to the corpuscles: and I have generally found the membrane of the corpuscle very delicate. It is, however, quite conformable to truth, to state that this membrane has a direct continuity with the arterial sheaths. (*Fig.* 527, 528.)

The corpuscles do not possess any connection with the trabecular network, still less that which Gerlach has lately attributed to them: viz. that they serve as points of support to the elastic fibres of the partitions; a belief which is altogether baseless.

It is difficult to say any thing definite respecting the number of the splenic corpuscles. Hessling believes that, in some cases, they constitute from one-fifth to one-sixth of the whole splenic mass; and this seems to me no overstatement, if we substitute the expression "spleen-pulp" for "spleen-mass." At least, I have found, that their quantity is very considerable; and that in some instances, when they are rather turgescent, the whole pulp appears as if besprinkled with white. They stand so thickly together, that in many places they touch each other's sides; and in others are only separated from each other by narrow interspaces, which in the least favourable circumstances are about one to two lines in size. I believe that the estimate, that one and a half to two lines of spleen-pulp contains one Malpighian corpuscle, is rather too little than too large.

As regards the lower animals, it would follow from my researches, that the Malpighian corpuscles occur in *Mammalia* in precisely the same way as in Man; at least, in more than twenty genera which I have examined, I have never found them to be absent. It has long been known that they are very distinct in pigs, sheep, oxen, goats, and so also in guinea pigs, hedgehogs, and bats, &c., in whom they are rather larger and more resisting than in Man; and although in the dog, cat, and rabbit, they are somewhat smaller and more covered by the pulp, yet they are nevertheless very distinct. As to *Birds*, Bardeleben seems to have recognised the Malpighian corpuscles in swallows, pigeons, and geese; while I have been able to verify their existence in sparrows, although they are not particularly distinct. So also Ecker briefly states, that he has seen them in birds; and Oesterlen mentions their occurrence in the fowl, pigeon, and in many of the *Raptores*. Amongst the *Reptilia*, J. Müller has detected them in the Chelonia; while I have seen them very distinctly in the anguis fragilis, in whom the corpuscles were surrounded by a beautiful network of capillaries. Amongst the *naked Amphibia*, Oesterlen states himself to have seen them here and there in toads and frogs; but in direct opposition to this, I have found no trace of them. Just as little have I been able to detect them in *Fishes*, although I have examined many of the fresh-water genera with this especial purpose. And thus the conjecture of Müller*, — that they exist in all the vertebrata, although in none so distinct or so easy of observation as in the vegetable-eating mammals — must be considered as incorrect: a cirumstance which is not without considerable interest in the determination of their import.

On inquiry into the more minute structure of the Malpighian corpuscles, it is exceedingly necessary to regard, not only their appearances in Man, but also in the lower animals. Each Malpighian corpuscle possesses a membrane and contents, and therefore is not a solid corpuscle, but rather a vesicle. The membrane which Malpighi beheld, was minutely described for the first time by Müller and Giesker. According to the first of these observers it is, as previously mentioned, a process of the common sheath of the vessels, which either immediately continues as a vesicular swelling of the same, or is previously produced into a peduncle. Giesker rejects this view, at least as regards the human subject, and describes in each corpuscle a peculiar, independent, and tolerably strong membrane, which seems to have no connection with the sheaths of the vessels, but receives an additional thin outer covering of white fibrous tissue, in which the vessels of the corpuscle ramify, and to which they frequently impart their own red colour. The majority of later observers have unconditionally adopted one or the other of these views; only a few of them, as J. Simon, Henle, Ecker, and Oesterlen, having taken the trouble of substantiating their truth by original inquiry. Henle, Oesterlen, and J. Simon, deny the existence of a special membrane. The first of these observers finds that the wall of the corpuscles is constituted solely of granules, under which appear to be comprised structures resembling the morphous part of the contents; while fine bundles of white fibrous tissue unite on their outer surface. Oesterlen and J. Simon likewise deny the peculiar membrane (limitary membrane), an absence which the latter associates with the capacity of the corpuscles to fill themselves out from the capillary vessels. So also Bardeleben describes a membrane very indistinctly.

* Physiologie, i. S. 486.

On the other hand, Ecker* has assured himself of the presence of a membrane in mammals and birds. By the application of potash, the masses of granules which seem to constitute the wall of the corpuscle were dissolved; and he then not only saw the ramifications of the arteries on the Malpighian corpuscle with great distinctness, but he also recognised that this possesses a distinct membranous wall, in which a network of exceedingly fine and well-defined stripes could be detected. Although these stripes are actual fibres, yet, according to Ecker, they everywhere cover a structureless gland-membrane, for the wall of the vesicle is never interrupted in the structureless intervals between these fibres; indeed it is possible that the latter are themselves but folds of a structureless membrane. Amongst the most recent authors, Arnold † and Huschke ‡ accept Giesker's view, and Dr. Gerlach § repeats Ecker's decision. As to myself, in the first place, I regard it as an incontrovertible fact, that the Malpighian corpuscles possess a special membrane. If one of the vesicles be isolated, and sufficiently separated from the surrounding tissues, it may be seen without any further preparation, especially with a slight pressure (*fig.* 527.); and it becomes particularly distinct if a little dilute soda or potash be applied (*fig.* 528.). These reagents dissolve all the surrounding parts of the pulp, with the exception of the vessels, and thus leave the membrane of the vesicle, although somewhat altered, yet quite entire. Concerning the nature of this membrane, I have verified the following: it is colourless, transparent, about 1 to 2-1000ths of a line in thickness, has everywhere two contours, and here and there it exhibits concentric lines. Its structure so far corresponds with that of the sheaths of the vessels with which it is continuous, that it contains at least white fibrous tissue and elastic fibres; but the unstriped muscular fibres which oc-

* Der feinere Bau der Nebennieren, 1846, S. 10.
† Anatomie, ii. S. 123.
‡ Eingeweidelehre, S. 178.
§ Zeitschrift für Rationelle Medicin, Bd. vii. S. 77.

cur in these sheaths in many animals, are altogether absent from the membrane of the Malpighian corpuscle; and the latter must especially be noticed as being much more delicate than the sheaths of the arteries on which the corpuscles sit. The white fibrous tissue, which Ecker regarded as a continuous membrane, in consequence of having seen it when changed by the action of potash, is in precisely the same condition as in the partitions and sheaths of the vessels, and forms by far the greatest part of the coat of the corpuscles; while the elastic tissue (the stripes of a doubtful nature which Ecker saw) appears to constitute only a more or less extensive network of pale, so-called nuclear fibres (kernfasern) (*fig.* 528. *b*). So that the membrane of the Malpighian corpuscles would thus appear to be only a modified portion of the vascular sheath, — a view which most approximates to that enunciated by J. Müller. An outer coat, of which Giesker speaks, has never been plainly verified by me as a special membrane connected with the preceding; but it seems to me more probable, that the corpuscles are always immediately surrounded by the cells and vessels of the pulp. Certainly these vessels are often connected together by an indistinct fibrous or membranous substance, but this is especially present in the pulp, and is nothing else than the termination of the sheath of the vessels. The preceding remarks especially apply to the Malpighian corpuscles of the higher brute mammalia. As to those of man, although they are much more difficult to examine, yet I have satisfied myself in the most positive manner that they correspond with those of the brute mammalia in all essential points. This is easiest and best seen in the spleens of children. The structure of these is exactly that seen in animals, only the coat is more delicate, so that it is extremely difficult to isolate a single corpuscle entire, and the contents are expelled by the slightest pressure. In the wall is seen the same network of elastic fibres as in animals, and this renders it possible even to recognise those which are burst. Extremely fine capillaries of 3-1000ths of a line in diameter may frequently be seen around the corpuscles; but the latter are just as little enveloped in a second membrane as in animals.

The Malpighian corpuscles do not possess in their interior an epithelium and separated contents like the glands, but they are densely filled with a semifluid, greyish white, cohesive mass (*fig.* 527. *b*). This contains, together with a small quantity of a clear fluid, a large quantity of morphous particles, which have been very differently described by different observers. According to J. Müller they very much resemble the corpuscles of the spleen-pulp, and have a general likeness to the blood discs, but are irregularly spherical. Bischoff regards them as altogether corresponding with those of the chyle, both in appearance, size, and behaviour with water and acetic acid. According to Henle, they resemble those of the spleen-pulp and those of the thymus and thyroid body; and he so describes them, that it would appear he recognised nuclei and a small proportion of cells. Oesterlen describes them as nuclei resembling the elements of the pulp. Hessling, Huschke, and Nasse* agree with Bischoff respecting the similarity of the elements in question to the lymph and chyle corpuscles. The latter of these authorities finds those of the rabbit to be 2—3-1000ths of a line in diameter, while Hessling certifies to their size in men as from 2—5½-1000ths, and describes their surfaces as possessing a mulberry-like appearance, and their contents as partly minute granules, partly separate nuclei. J. Simon found that the corpuscles in question never attained a development into cells. Remak† describes them as consisting — partly of large transparent cells, with an interior containing a single lateral, or double and clear nucleus — partly of small, dark-bordered vesicles, closely surrounded by a delicate pale membrane, and occupied by a dark central nucleus. The first, according to him, resemble the larger, the last the smaller lymph corpuscles. Finally, Gerlach finds in the Malpighian corpuscles the nuclei of cells, and, in equal quantity, cells of different sizes, with one, two, or three nuclei, as well as blood corpuscles, with all those forms of granule-cells which I shall hereafter describe as developed in the spleen-pulp from the effused blood.

These are the most important accounts given by others. As the result of my own researches, I must, firstly, corroborate J. Müller, who explains the elements of the contents of the Malpighian corpuscles and spleen-pulp as similar structures. Also, I can add with Bischoff, that they often resemble the chyle corpuscles; yet I am not disposed to lay any weight upon this correspondence. Furthermore, I consider it fully made out that Gerlach's view, according to which blood corpuscles, and cells which include blood corpuscles, are a constant constituent of the Malpighian corpuscles, is altogether erroneous. They are not even frequent occurrences, for in many animals I have not found them at all; and when they occurred — as, for instance, in oxen — they were mostly found in scattered vesicles, and, further, were in such small quantity, that they had no influence on their colour. And very often blood corpuscles and their metamorphoses appeared to occupy the vesicles, where a more careful examination showed that they were only in contact with their outer surface. The degree of accuracy to which Gerlach's assertion may lay claim is best shown by the fact, that he altogether denies the existence of these granule-cells (which are produced from the effused blood) in the spleen-pulp; while it is here, as well in these as in animals which possess no proper spleen vesicles, that they occur in

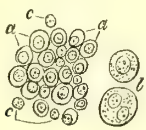
* Handworterbuch der Physiologie, von R. Wagner, ii. S. 387.

† Diagnostische und Pathogenetische Untersuchungen: Berlin, 1845.

the greatest quantity, and are most easily seen.

The constant and essential elements of the splenic vesicles are cells, with a single nucleus of a spherical shape, and from 3 to 5-1000ths of a line in diameter: besides these, free nuclei, and larger cells of 6-1000-ths of a line in diameter, and with one or two nuclei, also occur (*fig.* 529.). The cells are in general pale and faintly granular; their nuclei are from 16 to 25-10000ths of a line in size, spherical, apparently homogeneous, and with a rather dark margin; or frequently vesicular, with a more or less distinct nucleolus and other granules. It is not infrequent to see

Fig. 529.



Elements of the Malpighian corpuscles of the Ox, magnified 350 *diameters.*

a, smaller cells; *b*, larger cells; *c*, free nuclei.

single cells provided with dark fatty granules, and in particular instances blood discs are present, either changed or unchanged, free or included in cells. The free nuclei are of the same size as those contained in cells, and are also, in other respects, quite similar to them. In the ordinary method of examining the Malpighian corpuscles, the quantity of the nuclei seems larger than it really is, since many of the cells burst, and allow their nucleus to escape. Yet it is very remarkable that their number is very variable in the most cautious examination, a fact which appears to me partly to account for the very different statements of different observers. In many cases it has happened to me to find only a few free nuclei, often none at all, while in other instances they constitute a half or more of the elements of the corpuscles. This fact, taken together with the often very different size of the cells present, seems to prove that a continuous process of cell-growth exists in the Malpighian corpuscles; in such wise, that new nuclei and cells continually arise, and old cells perish. But hereof more will be said in speaking of the pulp, in which the same process obtains.

If, after these remarks, we take a glance at the import of the Malpighian corpuscles, we shall be compelled especially to ask ourselves, first, whether they are the beginnings of the lymphatics, or in any other way connected with them? and, secondly, whether they have the import of glandular vesicles? A connection of the Malpighian corpuscles with the lymphatics was a belief of many anatomists in earlier times, and in our own days has been recently upheld by Giesker, Huschke, Gerlach, and Poelmann. The acceptors of such a theory rest mainly on conjecture, but partially also on facts. Amongst the latter, there may be mentioned — 1. The correspondence of the cells in the Malpighian corpuscles with the lymph corpuscles. But we must remember that cells which correspond with the lymph corpuscles occur in many other situations where no such connection with the lymphatics can be imagined, as in the spleen-pulp itself, in the pancreas, in the salivary glands, the glands of mucous membrane, the thymus, thyroid, &c. 2. Huschke adduces the similarity of the spleen vesicles with the whitish granules of the lymphatic glands, which are dilatations of the lymphatic vessels themselves. Against this it need only be objected, that this latter is a pure fiction of Huschke's, and that even were it as he states, no conclusion concerning the nature of the Malpighian corpuscles could fairly be deduced from it. I have yet further to mention, that, according to an oral communication of Ecker which was made to me many years ago, and recently repeated, concerning the splenic vesicles of the mammalia, processes and pedicles exist which are neither blood-vessels nor partitions, and, therefore, may be lymphatics, — a view with which Poelmann's and Gerlach's recent statements are somewhat in unison. The former of these two* says that he followed the thoracic duct even to the Malpighian corpuscles, with which it became connected; but he does not specify more exactly the nature of this connection. The latter says that it has often seemed to him as if the neighbouring Malpighian corpuscles communicate with each other through special tubes; that he has been led to this belief by the circumstance that when the vesicles are compressed, their contents are expelled in definite directions, which a closer examination shows to be canals, the coats of which tolerably resemble in texture those of the Malpighian corpuscle; and that it is thence clear that the corpuscles communicate with a system of tubes which can scarcely be imagined to be any thing else than the lymphatics. And thus, if the Malpighian corpuscles are dilatations of the lymphatics, they may possibly be commenced as simple varicose swellings, or, what is more probable, as lateral productions of these vessels. I acknowledge that I am unable to verify this fact last adduced, or to subscribe to this connection of the Malpighian corpuscles with the lymphatics. In my researches I have given an attention to this point conformable to its great importance; and although I have not seen the commencement of the lymphatics in the spleen, yet I have so far come to a positive conclusion, that I am convinced of the complete closure of the Malpighian corpuscles. What Gerlach states of the tubes into which the contents of the corpuscles are forced, is altogether erroneous; such tubes nowhere exist. Gerlach appears to have been misled to this opinion by the fact, that when a corpuscle is burst by pressure, the contents rush out at several points,

* Annales et Bulletin de la Société de Médicine de Gand, 1846, p. 267.

and are then effused in the shape of long and small streaks in the surrounding tissues. If the commencements of such a streak were not observed, it might easily be regarded, from its always taking a radiating course from the Malpighian corpuscle to which it is united, as a canal communicating with the same, especially when a longer pressure applied to the corpuscles has elongated these stripes by continually forcing out the contents. The processes which Ecker has described on the Malpighian corpuscles, and which are not bloodvessels, probably belong to the same category as the artificial products mentioned above; or, if this is not the case, it is possible that they are small trunks of nerves, which are frequently present in the neighbourhood of Malpighian corpuscles, and which, from reasons that will be hereafter mentioned, are exceedingly difficult to recognise as being what they really are. I therefore maintain, quite plainly and definitely, *that the Malpighian corpuscles are closed capsules, and stand in no connection at all with the lymphatics.*

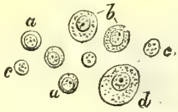
If this be so — and the structure of the Malpighian corpuscles, which altogether differs from that of vessels, corroborates the fact — it is next demanded may not the Malpighian corpuscles be glands? If by "glands" be meant the word in its ordinary sense, I answer with a decided "*no;*" for these altogether differ from the known simple shut glandular sacs of the ovary, thyroid, thymus, and supra-renal capsules, and possess neither a structureless membrana propria (limitary membrane, or basement membrane) nor an epithelium. On the contrary, in my opinion, they correspond with the spaces filled with cells in the lymphatic glands, and with the sacs of the glandulæ solitariæ and agminatæ of the intestine. Here and there hollow spaces exist, which possess a covering of white fibrous tissue, are completely inclosed, and contain in their interior no trace of epithelium, but only a coherent mass of nuclei and cells, together with some fluid; we might call these "*vesicular glands*," recollecting at the same time that they possess the function of the real shut glandular vesicles, although their anatomy essentially differs. Although the discussion of the former question does not belong to this part, yet I will add, that, in reality, there is much to indicate that the structures in question constitute a kind of shut glandular vesicle; and that, consequently, there is nothing to prevent their being regarded as glandular vesicles.

5. *The red spleen substance, the spleen-pulp, the parenchyma of the spleen* (*substantia rubra, pulposa, parenchyma lienis*), is a soft reddish mass, which fills up all the interstices between the larger partitions and the stronger vessels, and on section of the organ is easily scraped off or squeezed out. It consists essentially of three constituents; which are, fine bloodvessels, parenchyma cells of the spleen, and small partitions or fibres. To these constituents is so frequently added, both in man and animals, extravasated or coagulated blood in various metamorphoses, that one is almost forced to designate it a normal constituent. According to the predominance or diminution of the latter ingredient, or according to the greater or lesser distention of the bloodvessels themselves, the spleen-pulp appears sometimes altogether of the colour of the blood, at others of a clearish red, with a greater or lesser tendency towards whiteness.

The following remarks apply to the microscopic appearances of the constituents of the pulp, the vessels only excepted, which will be described hereafter. The fibres of the pulp are of two kinds. The one kind, which may be named "small or microscopic partitions" ("*microscopische balkchen*"), are quite analogous to those larger partitions ("*balken*") which are visible to the naked eye; they are also of the same structure, except that in the lower animals they often contain more muscular fibres than the latter. Their diameter is variable, from 5 to 10-1000ths of a line; their frequency and quantity also vary in different situations, and amongst different creatures. In the human subject I find them to be fewer and broader than amongst other mammalia, and exactly like the larger partitions in structure; while in the ox, sheep, &c., they occur frequently, are more delicate, and are remarkable by their purely muscular structure. The other fibres of the pulp are evidently processes from the sheaths of the larger vessels; they greatly predominate in quantity, and appear chiefly in the form of delicate membranes of an indistinctly fibrous structure, and without any mixture of elastic fibres, which seem to connect the capillaries to each other. Whether they take the form of small partitions — in which case they could not be distinguished from the small *trabeculæ* — is at present undecided. In animals, these membranes are also present on the veins; but of this more will be said hereafter, in speaking of the vessels.

The *cells of the spleen-pulp*, which I shall call "parenchyma-cells of the spleen," have been described by J. Müller as similar to those of the Malpighian corpuscles; and, as was previously stated, this view has been followed by the majority of writers; as by Henle, Bischoff, Huschke, Remak, and others. Only Von Hessling and Gerlach are of another opinion. According to the former, the globules of the spleen-tissue are distinguished by their dark colour, and by their being mingled with spindle-shaped cells. Gerlach finds that cells with nuclei are rare in the spleen-pulp; while, on the contrary, he considers them to be frequent in the Malpighian corpuscles. As to myself, I have already expressed my concurrence with the view taken by Müller, and may therefore forbear to enter further upon this point; nevertheless, it is necessary to remark that the parenchyma-cells exhibit some additional peculiarities, which ought not to be passed over without notice. A considerable portion of these cells completely correspond with the cells of the spleen vesicles; the characteristic appearances of which are their

Fig. 530.



Parenchyma-cells from the spleen of the Ox, magnified 350 diameters.

a, Smaller cells; *b*, cells of medium size; *c*, free nuclei; *d*, largest cells.

roundness, their size — from 3 to 5-1000ths of a line — their paleness, and their dark nucleus (*fig.* 530. *b*). On the other hand, smaller and larger corpuscles also occur in the spleen-pulp, which are never met with in the Malpighian corpuscles. The former are small round corpuscles, somewhat larger than blood globules. They are seen in one of two states: either they exhibit a membrane and nucleus inseparable from each other, and thus, apart from their colour and somewhat lighter outline, resemble blood globules; or they are free nuclei, in which no nucleoli are visible. But only a few of these are free nuclei, for by the application of saliva or a little water a membrane starts into view, either completely enclosing them, or limited to one side (*fig.* 530. *a*). The nuclei, which thus appear as something separate from the membrane, have always the dark appearance of those cells the two parts of which are inseparable from each other; so that the appearance of these latter would seem chiefly dependent on the nucleus. With these small and quasi-developing cells, one also meets with free nuclei; and careful manipulation of the preparation shows these to be in general more numerous than in the Malpighian corpuscles (*fig.* 530. *c*). The larger named corpuscles are partly pale cells of 7-1000ths of a line in size, with one or two nuclei; or granule-cells of 4 to 6-1000ths of a line, and which may be described as "the colourless granule-cells" (*fig.* 530. *d*): both of these are more frequent than in the Malpighian corpuscles. The spindle-shaped or fusiform cells which Hessling mentions do not belong to the normal constituents of the spleen-pulp, and are nothing else than epithelium cells of the splenic arteries (*fig.* 534. *b*), which in macerated specimens of the human spleen, and in preparations where the vessels have been cut through, easily get into the pulp, and give rise to the delusive appearances of the so-called fusiform cells. The comparative examination of this part of the spleens of many animals confirms what has been already stated of the elements of the Malpighian corpuscles; namely, the elements of the pulp vary greatly, since sometimes the nuclei, sometimes the smaller cells, sometimes the greater cells, predominate. And in this, as in the former case, I conclude therefrom that a continuous process of cell growth obtains in the spleen, by which new cells are formed around nuclei, and old ones disappear.

The quantity of parenchyma-cells of different kind and shape, and of free nuclei which must be reckoned with these, is a very considerable one; so much so, as to constitute nearly one half of the whole red spleen substance. These do not lie collected in large heaps, but constitute small irregular groups of different size, which occupy the interspaces formed by the partitions of all sizes, the vessels, and the Malpighian corpuscles. The best method of representing this disposition is to regard each part of the pulp, which is included in a large mesh by trabeculæ visible to the naked eye, as constituting in a small form what the spleen itself is in a larger. The microscopic partitions and fibres and the finest vessels thus exhibit the same relations as the larger partitions and vessels; while the small nests of parenchyma-cells answer to the large homogeneous masses of red pulp which are visible to the naked eye. There are nowhere any special coats which include these cells, but they may be seen everywhere placed immediately on the sheaths of the vessels, the partitions, and the membranes of the Malpighian corpuscles. In the above delineation of the parenchyma-cells, those of man and of the higher mammalia have especially served as the model: but in general a complete similarity obtains in other animals; and it is only here and there that any specialities show themselves. In many animals — thus, for instance, in amphibia — the spleen has often, though not always, very beautiful parenchyma-cells with large nuclei: in birds, and in the scaly Reptilia, granulated and somewhat dark cells are for the most part more frequent. In the hedgehog, rabbit, and guinea-pig, some cells, which are altogether peculiar, occur in company with the ordinary ones. In both the former of these I saw, here and there, large round cells from 10 to 16-1000ths of a line, with three, four, to ten or more nuclei, which often lay so closely together in the middle of the cell that they appeared to make up a mulberry-like mass, like certain large cells which one finds in the marrow of young bones. These cells were by no means uncommon, but gradually diminished in size towards that of the parenchyma-cells. In the guinea-pig occur round cells, in large quantity, of 48 to 60-10000ths of a line, which contain one or seldom two round granules of a dark contour; and their nucleus, not always very distinctly visible, is very plainly seen on the application of acetic acid; while, at the same time, the dark granules often disappear.

The *blood effused in the spleen-pulp*, as well as the *metamorphoses of the blood globules* in the same, demand the greatest consideration both in respect of anatomy and physiology. I believe myself to have been the first who* directed attention to this circumstance, and cor-

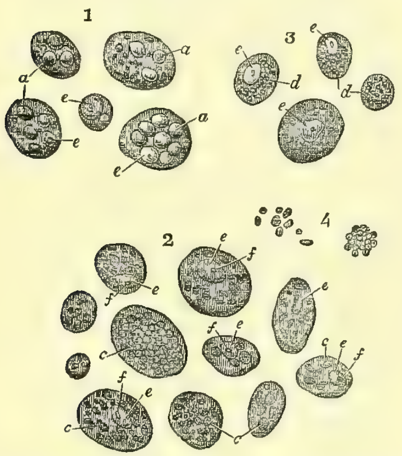
* Loc. cit.

rectly recognised it; although Oesterlen, Remak, and Handfield Jones had already detected isolated facts having a reference to it. Oesterlen * was the first who found in the spleen of frogs and toads, and with less distinctness in that of the mammalia, yellow, rose-red, and black minute corpuscles, but he was not in a condition to explain them. Remak followed next without greater success; he found in the spleen-pulp of the calf delicate transparent vesicles, with 1 to 3 round, reddish-yellow homogeneous bodies, the colour of which approximated to that of the blood corpuscles, but which were not so easily swollen out by water. Finally, Handfield Jones † discovered peculiar yellow corpuscles in the spleen of different vertebrata.

All these facts are placed in their true light by my discovery that blood corpuscles are almost constantly undergoing dissolution in the spleen and disappearing. This will be shown as follows: —

The red pulp of the spleen in man and animals exhibits at different times a different

Fig. 531.



Cells containing blood corpuscles from the spleen of the Rabbit, magnified 350 *diameters.*

1, cells with one, three, four, and seven unchanged blood corpuscles; 2, cells with blood corpuscles undergoing dissolution, and coloured in different shades of brown or yellow (coloured granule cells); 3, cells with destroyed and decolorized blood globules, larger or smaller, and with or without granules; 4, blood globules altered in colour, diminished or destroyed, either single or aggregated, in small clumps.

In 1, 2 and 3 the following letters signify alike: — *a*, more or less unchanged blood globules; *c*, colored granules begun by a diminution or destruction and alteration of colour in blood corpuscles; *d*, colourless granules produced by the discoloration of *c*; *e*, nuclei of the cells containing blood corpuscles and their metamorphoses; *f*, nucleoli of these nuclei.

colouring, or rather a different condition of the blood corpuscles contained in it, and these, without any participation of the other elements, affect its colour by the different nature of their appearances. Thus, in a particular animal or in the human subject, this substance sometimes possesses a paler or more greyish red, sometimes a brown, or even black-red colour: in the latter case a quantity of altered blood globules are present, the appearances of which will hereafter be described; while in the former case, it may easily be proved by the microscope that the red colour depends on unaltered blood globules, which are easily separated from the pulp by pressure, and on the application of water give off all their colour in a short space of time. In other animals, the spleen has always about the dark colour mentioned: nevertheless, even in these cases, sometimes only unchanged blood globules are seen; sometimes many of these are undergoing the most manifold changes.

Now these changes (*figs.* 531, 532.) are very extraordinary and peculiar, and in all animals depend essentially upon these facts. The blood globules first become at once smaller and darker, while the elliptical corpuscles of the lower vertebrata also become rounder: then, in connection with some blood plasma, they become aggregated into small round heaps; which heaps, by the appearance of an interior nucleus and of an outer membrane, experience a transition into spherical cells containing blood corpuscles. These are from 5 to 15-1000ths of a line in size, and contain from 1 to 20 blood corpuscles (*figs.* 531. 1. 532. 1.) During this time the blood corpuscles are continually diminishing in size, and, assuming a golden yellow, brownish-red, or dark colour, they undergo, either immediately or after a previous dissolution, a complete transition into pigment granules. So that these cells themselves are changed into pigmentary granule-cells; and, finally, by a gradual loss of colour of their granules, they form themselves into completely colourless cells (*figs.* 531. 3. 532. 4.).

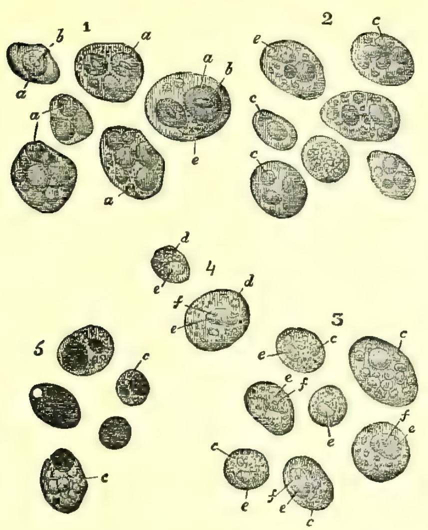
In respect of the more special circumstances of this process, it is first necessary to consider the commencement of the cells described, and their changes, somewhat more in detail. As regards the first of these, it is certain that the cells containing the blood corpuscles do not commence directly around a nucleus, but by the circumposition of a membrane around a heap of coagulated blood: in the same way, to wit, that the so-called inflammatory globules of Gluge in certain cases change themselves to cells; or that by which the smaller globules of fission of the yolk form themselves into vesicles. On the other hand, it remains doubtful whether the nuclei which are seen in these cells are there before the formation of the membrane, or whether they only begin as supplementary to it. If the former be the case, one might add that, in the extravasated or clotted blood of the spleen, nuclei arise in consequence of the commencing organization, each of which then, like the nuclei in the fission of the yolk,

* Loc. cit. p. 52.

† London Medical Gazette, Jan. 1847, pp. 140-142.

surrounds itself with a part of the blood (plasma and globules), and, finally, conditionates the development of a membrane on the surface of the sphere thus commenced. Or one might regard the formation of spheres consisting of some blood plasma and blood globules as the primary phenomenon; and that then a nucleus begins in each sphere; and that, finally, a membrane is thrown around these. In corroboration of this opinion, Hasse and myself* have observed in the pigeon the occurrence of inflammatory globules, which are without nuclei or membranes, but contain blood globules; and to this may be added, that in the splenic extravasations blood corpuscles are often grouped together in heaps without being contained in cells. Be this as it may, in any case thus much is certain, that as soon as the cells with their included blood globules are visible, the nuclei are never absent; and this fact, taken in conjunction with what is already known of the import of nuclei in the process of cell development, speaks strongly for their formation preceding that of the membrane of the said cells.

Fig. 532.



Cells containing blood corpuscles, from the spleen of the Frog (Rana temporaria and esculenta), magnified 350 diameters.

1, cells with one or more blood globules of an intense yellow colour, diminished in size, yet mostly not yet destroyed; 2, cells with blood globules coloured brown, orange, or black, still more diminished and dissolved (coloured granule cells); 3, cells with blood globules much diminished or quite dissolved, and undergoing discolorization (pale-coloured granule-cells); 4, cells with completely dissolved and discolorized blood globules (colourless granule-cells); 5, coloured granule-cells (like those in 3) in different stages of their transition into black pigment-cells.

In 1—5 the letters import, as in *fig.* 351. *b*, the nuclei of the blood globules.

These cells containing blood corpuscles behave themselves so far alike in all creatures, that their blood corpuscles by degrees disappear and fall to the ground; and, ultimately, they all seem to be converted into colourless cells, although the methods by which this change occurs are different in different animals; whence it will be well to go through them one by one.

a. In *mammals* the cells with unchanged blood corpuscles are not very easily seen, on account of the small size of the latter, and the facility with which they lose their colour; yet one can easily get a sight of them, provided the examination be made at the right time, and the application of water forborne. I have seen them plainly in man, the rabbit (*fig.* 531. 1.), guinea-pig, sheep, calf, and dog; and have found that in these creatures the number of the included blood globules is from 1 to 12, on an average from 2 to 6, and the size of the cells from 5 to 16-1000ths of a line; while their vesicular nuclei have a length of 36-10000ths, and a breadth of 28-10000ths of a line. By the shrinking up and falling to pieces of the blood globules, which immediately renders them darker in colour, coloured granule-cells begin from these cells. They are of a golden yellow, or rusty or brownish yellow, or even blackish colour (*fig.* 531. 2.), and gradually experience a transition into cells, with slightly coloured, more numerous, and smaller granules; and, finally, they take the form of altogether colourless cells, part of which are even poor in granules (*fig.* 531. 3.). In man, the rabbit, and the guinea-pig were found, besides the cells just described, free granules and heaps of granules, of a golden yellow, brown, or blackish colour; together with altered blood globules, concerning which it seemed to me very probable that they were originally free, and were never included in cells. In other vertebrata, as in the hedge-hog, the cat, and the bat (*Vespertilio myotis* and *pipistrellus*), the cells with the unchanged blood globules were not observed, although all other stages, from the golden yellow to the altogether colourless granule-cells, were seen. Finally, in others, as in the horse and ass, were seen uncommonly numerous, diminished, and highly coloured blood-globules, both isolated and aggregated; and the metamorphoses of these into golden, brown, and blackish-yellow heaps of granules, although no definite indication of cell structure could be detected around these heaps.

b. Amongst *birds*, I have found the round cells in Falco albicillus, Cuculus canorus, Turdus varius, Perdix saxatilis, and Sylvia hortensis. They were in larger or smaller quantity, from 4 to 10-1000ths of a line in size, with dark golden yellow granules which were evidently nothing but metamorphosed blood globules. This was very distinctly shown in Turdus musica, since here the cells occurred with unchanged blood globules. Everywhere these cells experienced a transition, partly into brown and black granule-cells, partly into colorless granulated cells.

c. Amongst the *Reptilia*. In the *scaly*

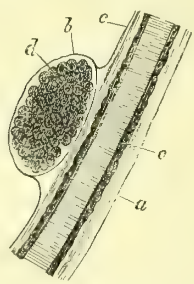
* Zeitschrift für Ration. Medicin, Band. iv. S. 1.

Reptilia, amongst which I have only examined Anguis fragilis and Coluber austriacus, I have seen no cells with unchanged blood globules; but in the Anguis I found pale yellow, brown, and black granule-cells, which were, as in birds, of from 6 to 10-1000ths of a line in diameter. Transitions of these into faintly yellowish and colourless granule-cells were also present in considerable number, being almost as frequent as the ordinary parenchyma cells in the spleen-pulp. The Coluber austriacus certainly exhibited an effusion of blood in the parenchyma of the spleen, but no changes of the blood corpuscles. The *naked* amphibia offered a striking contrast. Amongst them I examined Rana temporaria and esculenta, Bombinator igneus, Hyla arborea, Bufo cinereus, Alytes obstetricans, Salamandra maculata and atra, Triton igneus, tæniatus, and cristatus. The cells with blood globules were better seen in these than in any other animals. This was especially the case in Triton, Bombinator, and Rana, in which 5, 10, 20, and more blood globules, with distinct nuclei, were frequently seen occupying a plainly nucleated cell of 6 to 12-1000ths of a line in diameter. The size of the blood globules in these cases allowed their metamorphoses to be followed through all stages, as is represented in *fig.* 532. At first they were round, of an intense yellow, and less easily altered by water; then they contracted themselves yet more together, assumed a golden yellow or brown yellow colour, and were no longer assailed by water; finally, they became colourless, or experienced a transition into black granules, while they generally also fell asunder into smaller granules. In this manner golden and brownish yellow granule-cells (*fig.* 532. 1.) arise from the cells with unchanged blood globules (*fig.* 532. 2, 3, 5.), and finally they experience a transition into colourless granule-cells (*fig.* 532. 4.), or exist for a longer time as black pigment cells.

d. In *fishes* I have recognised the same conditions as in the naked amphibia, only they were not so brilliant. The cells with blood globules were very distinctly seen in Salmo fario, Cyprinus carpio and brama, Tinca chrysitis, Esox lucius, Perca fluviatilis, Coregonus muræna, and Gadus lota. In Anguilla fluviatilis, Aspius alburnus, Chondrostoma nasus, leucocephalus, &c., they were less plainly seen; nevertheless, cells with shrunken blood corpuscles, or aggregates of such, occurred also in these. In all fishes these structures become converted partly into colourless granule-cells, partly into black pigment-cells and pigment masses, which finally often lose their colour.

The *place* where the changes of the blood corpuscles above mentioned occur can be demonstrated in some amphibia to be the bloodvessels. Thus, in Triton igneus, the spleen is at its margins tolerably transparent, and here one frequently comes upon the cells which contain blood corpuscles, occupying the capillaries in a row one after another; and here we are also able to drive them into the larger venous channels by pressure, so that one of these is often filled by a considerable streak, consisting entirely of these altogether characteristic elements. Whether this occurrence is a rule in the Triton, and whether it obtains in other amphibia, I am unable to certify. Yet I may communicate that, in the Triton, frog, toad, and Salamandra atra, I have found these cells containing blood corpuscles even in the trunks of the splenic vein and vena portæ; while in Bufo cinereus, Triton igneus, and Salamandra, I have found them in the hepatic branches of the vena portæ, even to its capillaries; and in the latter animal, even in the inferior cava and the heart. In any case, these facts may be considered as conclusive of the not unfrequent occurrence and formation of the cells in question within the bloodvessels of the spleen; although it can scarcely be added that they are not probably also formed in the extravasated blood. In certain genera of fishes, as in Tinca, Esox, Perca, the cells which contain blood corpuscles, and their metamorphoses, are seen included in round delicate-walled vesicles of from 1-40th to 1-16th of a line in diameter (*fig.* 533.), which for the most part

Fig. 533.



Artery (a), with a cyst (b) in its tunica adventitia (c), which contains cells (d) enclosing blood corpuscles. From the spleen of the Tinca chrysitis.

sit on the ramifications of the splenic arteries, either laterally on the vessels, or on the points where they divide; and which are connected with the sheath or exterior membrane of the same; or, in other words, are nothing else than *pouchings* of the same. How these vesicles are developed I have not determined, yet I can scarcely doubt that they have the import of false aneurisms, and owe their origin to a tearing of the inner and middle tunics, and to a protrusion of the tunica adventitia, together with the sheath of the vessels (if the latter texture can be supposed to exist here). The similarity of these vesicles with the Malpighian corpuscles of the mammals seems to be especially worthy of mention. After the description already given of the relation of the Malpighian corpuscles to the arteries, it is unnecessary to explain in detail, that the correspondence of both in respect of their site is very great. But, in respect of their contents a similar resemblance is sometimes exhibited, when, as in the cysts of fishes, the cells with blood corpuscles have all undergone a transition into colourless cells, or the Malpighian corpuscles contain effused blood. By pondering upon these circumstances, one might almost come to the idea of regarding the cysts of fishes as Malpighian corpuscles, or the Malpighian corpuscles of mammals as false aneurisms of the splenic arteries ; but in my opinion either of these views would be altogether erroneous. For although blood is often present in the Malpighian corpuscles, yet this appearance is *much too seldom* to allow of our explaining their contents as arising out of altered blood. And as regards the cysts of fishes, they are altogether absent from many fishes, and, where they are present, often undergo a cretification, or are changed into concretions ; while they occur in other organs, as for instance in the kidneys : facts which have little conformity with the constant occurrence of the Malpighian corpuscles. In others of the fishes previously mentioned, no vesicles can be recognised in the spleen; on the contrary, in many genera, the blood corpuscles obtained in different conditions of their metamorphosis are seated together in roundish heaps of a more or less definite outline, and of a size which equals that of the vesicles : these are evidently nothing else than extravasations of blood. The numerous circumscribed red or brown points which occur in the spleen pulp of all fishes, are nothing but the self-decomposing blood globules ; and they are, as above mentioned, either free or arranged in masses which are included in vesicles. In the scaly reptilia, birds, and mammals, it is very difficult to state with certainty in what part of the spleen the formation of the cells which contain the blood corpuscles and their metamorphosis occurs. At first I thought of the hollow interspaces with which the vein of the spleen begins; only these spaces, as will be shown hereafter, do not in the least obtain in the human subject in the form which has been hitherto attributed to them. Or the branches of the veins, which are always large, might easily be regarded as the locality, provided that the occurrences above mentioned be not regarded as extravasations. With regard to this question direct observation teaches us as follows. In the capillaries and arteries of the spleen in mammalia no changes of the blood corpuscles exist; so that the only question is, whether the blood corpuscles, which constantly occur in the spleen-pulp, and here undergo their metamorphoses, are situated in the commencements of the veins; or whether they occupy spaces newly formed by the extrusion of thē blood. Much may be adduced in support of the first of these views. Thus, it is scarcely possible to suppose that extravasations of blood in such extraordinary quantity constantly occur in the spleen; then it may also be mentioned that pigmentary granule-cells, such as are developed in the spleen from the blood, may also be found in blood-vessels exterior to the spleen, which seems to speak for their being situated within the vessels in the case of the spleen itself. I have myself formerly found scattered pigment-cells in human blood * which I can now only regard as granule-cells from the spleen. Ecker has also seen † in the splenic veins of the calf, cells containing blood corpuscles like those in the spleen. And, lastly, Meckel ‡ has also found black pigment-cells in the blood of a woman whose spleen abounded in them. Finally, we may recollect, that in the amphibia the cells in question are certainly situated in the vessels. But, on the other side, it must not be forgotten that in the spleen of fishes metamorphoses of the extravasated blood take place, and that also portions of the extravasations enter the vessels, and that it is possible the pigment-cells in the blood may thus originate ; finally, that the masses of blood in the spleen-pulp are scarcely defined with the sharpness which they would possess even in veins with very delicate coats. In this state of things it is much better to abstain from giving a definite decision ; or if one be absolutely required, to attribute the metamorphoses of the blood in the spleen of mammals to both the localities mentioned.

The changes of the blood globules in the spleen are not exactly similar in all circumstances, either as regards the quantity of the cells thus changed, or the degree of metamorphosis which they undergo. In *fishes*, all the blood globules, without exception, may be recognised as decomposing; yet the quantity of these varies, *i. e.* the number and size of the vesicles and masses previously described varies in a considerable degree in different individuals and species, although no very definite laws have as yet been found out. *Reptilia* exhibited the following peculiarity. In newly-caught individuals, the cells containing blood corpuscles were very numerous and distinct ; but in those which had fasted one, two, or three days, they occurred in exceedingly small quantity ; while, finally, by a longer duration of the fasting (a week or more), they exhibited themselves in very great number, and of extraordinary distinctness ; while at the same time the spleen became large, dark red, and very rich in the normal blood corpuscles. When newts which had fasted a week were fed, the cells previously existing, and the unchanged blood corpuscles, vanished, since they were changed into colored granule-cells, and only on the sixth day after the feeding did such cells reappear ; but in three days afterwards almost all of these had again experienced a metamorphosis into granule-cells. In *mammalia* I have, in a series of cases, seen the decompositions of the blood corpuscles in as little as five, six, and more hours after eating, while immediately after the reception of food, or after a day's fasting, I have failed to observe it. At my advice, Landis § instituted experi-

* See also Fahrner, De Globulorum Sanguinis origine: Turici, 1845, p. 26. fig. 143.

† Zeitschrift für Rationelle Medicin, Band vi. S. 264.

‡ Zeitschrift für Psychiatrie, 1847, S. 22.

§ Beiträge zur Lehre über die Verrichtungen der Milz: Zurich, 1847.

ments concerning this on thirty rabbits, and obtained the following results. Of fifteen animals which were examined, two, five, and eight hours after eating, cells with unchanged blood globules were found in eleven ; in five they were in masses ; in six separate ; in four cases they did not occur at all. Fifteen other animals, which were killed twelve, twenty-four, and forty-eight hours after eating, showed in eleven cases no trace of the cells mentioned; in two cases many were present, in two cases a few only. And, *vice versâ*, golden yellow granule-cells (*metamorphoses* of the cells with unchanged blood globules) occurred fourteen times in the latter animals; ten times in great quantity, once in considerable numbers, and three times very sparingly, while in one instance only were they altogether wanting. In the fifteen animals first mentioned these were twice absent, five times sparingly present, twice in considerable numbers, and six times in large quantity. The conclusion to be deduced from these facts is, that cells with unchanged blood globules only show themselves a short time after eating, and that the granule-cells which proceed from these are almost always present, although in greater number in animals which have fasted a considerable time. If any animal were examined at the proper time, one would be astonished at the uncommon quantity of decomposing blood globules; for in such a case the whole red part of the pulp consists (so to speak) of nothing but golden yellow or blackish corpuscles, which are the different metamorphoses of blood corpuscles already mentioned.

Of the *ultimate destiny* of the blood corpuscles so metamorphosed, thus much is certain,—that they are decomposed and dissolved ; but, on the other hand, it is difficult to make out what is the destiny of the cells which usually enclose them We have already seen above that these cells occur in the splenic vein, the vena portæ, and the inferior cava, and it is thence questionable whether all these cells may not possibly pass into the blood. It is difficult to give an answer to this. Thus much I consider to be made out : —that cells with unchanged blood globules, and yellow, brown, or blackish-yellow granule-cells, only exceptionally and seldom pass into the blood of the splenic vein, or beyond ; since, in the first place, these cells are, upon the whole, rarely found in the blood ; while, secondly, their occurrence in the spleen is demonstrably very frequent. On the other hand, as to the colourless granule-cells which finally arise from the cells containing blood corpuscles, it is not made out whether they remain in the spleen or enter the blood. Supposing the first of these to be the case, they may either abide a considerable time in the pulp, and then in a certain manner serve as parenchyma-cells, with which they have a great similarity, or they may experience a dissolution, and altogether disappear. In the second case, one may imagine that they are converted into lymph corpuscles, with which they have, to some extent, a great similarity, or that they undergo a solution in the blood of the portal vein and the rest of the circulation. I own that I cannot hazard a decision. It is certain that colourless granule-cells occur in the blood as well as in the spleen ; but it is also certain that they are much more frequent in the spleen, and that, as regards the blood of extravasation which undergoes metamorphosis, it may be definitely stated, that its products for the most part remain in the same place.

So much for my experience of the decomposition of blood corpuscles in the spleen. Simultaneously with myself, Professor Ecker, of Basle, made similar observations, which likewise referred to a destruction of blood corpuscles, and which, soon after, lent an additional light to mine.* In contradiction to this, however, Gerlach has lately uttered the opinion that my observations allude to the formation of colored corpuscles within colorless ones; so that he explains the forms of cells which are found in the spleen in precisely the reverse way, and supposes that the cells with golden yellow granules are the younger, and those with unchanged blood corpuscles the elder ; that is, that they are those in which the blood corpuscles have completely developed themselves, and from which they are ready to be expelled or set free. So that if Gerlach be correct, the relation of the blood corpuscles to the spleen is precisely the reverse of that which I have stated, and they begin there in great quantities ; and it thus becomes important to inquire whose opinion is the correct one. But if my experiments upon the behaviour of the blood corpuscles in the spleen have no other consideration, this merit, at least, remains to them, that they accurately set forth the anatomical facts, and in this manner have already sufficed to refute such false theories as that of Gerlach. In point of fact, Gerlach is altogether wrong when he supposes that the golden yellow granules are changed into blood globules ; for this can in no way be proved, but very easily the contrary. He is equally in error in adducing, as a ground for this view, that blood corpuscles begin as cells in the embryonal liver,—a statement which is altogether incorrect. And when he finally adduces that since, according to Harless †, the blood corpuscles are destroyed by the alternating influence of nitrogen and carbonic acid, a second kind of solution of these in the spleen cannot be conceived ; it need only be remarked that this theory of Harless's is not in the least proved as regards the living organism. So, also, Virchow ‡ has expressed himself as partially against mine and Ecker's account; since, though he does not at all doubt the dissolution of blood corpuscles, yet he altogether denies the origin of cells around

* Loc. cit.

† Ueber den Einfluss der Gase auf die Form der Blutkugelchen : Erlangen, 1846.

‡ Archiv für pathologische Anatomie und klinische Medicin, Band i. SS. 452. 483.

heaps of blood corpuscles. This statement is only explicable by supposing that the Mammalia and Reptilia, in ~~whom~~ this phenomenon can be seen as plainly as could be wished, were not examined by Virchow. Besides, I do not maintain that the effused blood always forms cells containing blood corpuscles; only I hold it as a fact established beyond all doubt, that this very frequently happens in the spleen as well as in extravasations in the lungs, lymphatic glands, brain, and thyroid body; and while I believe that the formation of cells around these several effusions is not an equivalent fact, yet it is altogether certain that blood globules enclosed in cells undergo a more speedy dissolution than if they remain free.

In conclusion, one word concerning the import of the changes of the blood corpuscles in the spleen. It may be asked, whether they constitute a normal and physiological, or a pathological appearance? On the one side, very weighty grounds may be alleged for the normal character, especially their (so to speak) *constant* occurrence and innumerable quantity in such a number of animals living in their natural condition, as the amphibia and fishes were. Furthermore, the apparently complete health which existed in spite of the vast quantity of dissolving blood globules. Thirdly, in Reptilia, the cells containing blood corpuscles may be seen in bloodvessels which are in no way isolated from the general circulation. Fourthly, similar and constant changes of the blood repeated at short intervals are absent from other organs of birds, mammals, and reptiles; and many other arguments might be adduced. But, in contrast to these facts, many others appear on a more careful contemplation, which may almost lead to the opinion that all the changes of the blood globules in the spleen are possibly only pathological appearances. In fishes, dissolutions of the blood corpuscles occur not only in the spleen, but in an exactly similar way in other organs, namely in the kidneys, the liver, and the peritoneum. In the first of these organs their presence is *constant;* at least, in the examination of many examples of eel, pike, Coregonus muræna and murænula, Salmo fario, Barbus fluviatilis, Cyprinus brama and carpio, and Tinca chrysitis, not only were they always present, but almost always as numerous as they were observed to be in the spleen. In the peritoneum and the liver they were sometimes scarce, sometimes frequent, but only in the carp and Tinca chrysitis were they constant; in other fishes they were either altogether absent, or only occurred here and there, as in the trout. If to these facts be appended that in certain animals,—to wit, in cats, sheep, and others,—the changes of the blood corpuscles in the spleen are very seldom observed, one can scarcely resist the notion that the appearance is abnormal; and this is much more the case when one considers that similar appearances which are known not to be physiological, constitute almost constant occurrences, and are associated with exactly parallel changes of blood globules. Of this, the small effusions of blood in the lungs, bronchial glands, and thyroid bodies of men, and those of the lymphatic glands and mesentery of pigs and rabbits, are instances. But this latter view is insusceptible of full explanation; for although pathological effusions and metamorphoses of blood often constitute almost a constant occurence, yet, first, the quantity of blood globules which undergo dissolution in such effusions is in no comparison at all with that of the millions which are destroyed in the spleen; and, secondly, it has yet to be shown that effusions of blood may not occur as a physiological phenomenon, as happens in the bursting of a Graafian follicle in the ovary, in menstruation, and in the separation of the placenta. And although all animals do not show in the spleen such a solution of the blood corpuscles as can be verified by the microscope, yet it is by no means proved therewith, that where ~~this~~ takes place it depends on a pathological condition; indeed, the blood corpuscles of different animals may undergo dissolution in different ways. At least thus much is certain, that in all animals, without exception, stagnations of blood occur in the spleen; and I might add, almost of a certainty, in mammals, extravasations also. In these stagnations, the blood globules may dissolve themselves in the one case *rapidly,* in the other case *slowly*, and thus, according to the outer phenomenon, a *difference* will be produced. Such an occurrence may be *physiological,* since it is, at least in many animals, visibly *constant* and very extensive; and it may have the greatest signification to the life of the organism. Therefore, so long as the pathological character of the phenomenon is not proved of a certainty, I am disposed to hold fast by its physiological nature, and to consider the dissolution of the blood corpuscles in the spleen as a normal fact.

6. *Bloodvessels of the spleen.* — The *splenic artery* (*arteria lienalis*) springs from the cœliac axis, and courses with many windings between the layers of the gastro-colic ligament until it reaches the fundus of the stomach, where it enters the gastro-splenic ligament, after giving off some small twigs to the pancreas and the stomach. Arriving in the neighbourhood of the hilus lienalis, it divides into a superior and an inferior branch. The upper of the two, passing somewhat upwards, and giving backwards from two to six short arteries (*vasa brevia*) to the large extremity or pouch of the stomach, divides into from three to six branches, which, lying in a line one over another, extend to the hilus, into which they enter. The inferior branch is somewhat larger than the others; it passes to the inferior and anterior part of the spleen, supplying it with three to six branches, which enter the hilus in the same manner as the others, and it ends finally as the gastro-epiploica sinistra. Thus, all the six to twelve branches which enter the spleen lie tolerably

in one line upon each other in the gastro-splenic omentum, and they are also connected to each other by fat and areolar tissue. The size of the splenic arteries is very considerable in proportion to that of the organ, and so also the thickness of their coats is worthy of notice. In the first of these respects, it is possible that only the thyroid gland exceeds the spleen; the liver, which is so much larger than this organ, being supplied by an artery of scarcely larger size than the splenic, although we must not overlook the fact, that beside this the liver receives very much additional blood through the vena portæ. In the mammalia generally, the splenic artery is proportionally smaller than in men; this possibly depends only upon the more considerable contraction of the vessel at their death. Wintringham finds that the thickness of the arterial coats is greater than that of the aorta above the giving off of the renal arteries, to which it bears the ratio of 1 to 0·762; he also states that they will sustain a pressure of 41 lbs.

The serous covering of the spleen receives some unnamed small arteries: thus a twig is given to it from the left inferior phrenic artery, which courses in the phrenico-lienal ligament; and, besides this, it receives branches from the first lumbar, from the left spermatic, and from the splenic itself. Additionally to these, in some of the vertebrata, to wit in the calf, small twigs in great number leave the substance of the spleen, and after perforating the fibrous coat of the organ spread themselves out upon its surface.

The *splenic vein* altogether corresponds in distribution to the splenic artery. So many primary arterial branches enter the hilus of the spleen, and just as many veins come out of it. These six to twelve veins unite into two branches, and receiving, the upper the venæ breves from the stomach, and the lower the vena gastro-epiploica sinistra, they constitute the trunk of the vein. In the spleen, and at their emergence from it, the veins lie anterior to the arteries, but then they place themselves posteriorly to them; and it is behind the arteries that they unite to form the common trunk. This trunk receives a twig from the pancreas, from the lymphatics of the spleen, from the stomach, and, further, the vena coronaria ventriculi; it then passes away over the aorta to the under surface of the liver; and, finally, with the vena mesenterica superior it constitutes the trunk of the vena portæ.

The splenic vein, like all the branches of the vena portæ, has no valves, and is the largest branch which assists to form that trunk. Its width is very considerable: according to E. Home* and Giesker, the proportion to that of the arteries is as 5 to 1; and according to earlier authorities it is yet more. The proportionate size of the branches is still larger; and, according to C. A. Schmidt, their ratio in the spleen itself to that of the arteries which run with them is as 20 to 1. In contrast to this, the thickness of their coats is very inconsiderable, and, according to Wintringham, is to that of the arteries as 1 to 4·8 or 4·3, to that of the iliac vein as 1 to 3·5.

On their entry into the spleen, both arterial and venous branches receive as a covering a process of that "tunica propria" of the spleen which forms the *vaginæ vasorum*, previously described.

These are not alike in all animals: thus, for instance, they differ in man from those exhibited by the higher brute mammalia — a fact which explains the various descriptions given by different authors. In man, the sheaths of the vessels form *complete* coats around them. A section made in the centre of the hilus, and continued through the spleen, exhibits them very distinctly as projections or processes of the tunica propria, and also allows their further circumstances to be seen. It is thus shown that arteries, veins, and nerves are thickly enclosed in these sheaths; but in such wise that they are easily separated and isolated, especially in old, or macerated, or boiled spleens. The arteries and nerves allow of this more easily than the veins, which latter have a closer connection to these sheaths. It is further seen that not only are the trunks of entering and emerging vessels thus covered, but that their finer ramifications receive a similar clothing. The thickness of these sheaths is in the human subject by no means inconsiderable. As Giesker correctly states, they are at first exactly the thickness of the tunica propria, and retain the same thickness for a considerable distance, that is, as long as they clothe the main trunks of the vessels. On the branches which proceed laterally from these trunks, and on their further extent, the sheaths become naturally finer, and gradually increase this fineness as the vessels become more minute, until finally, becoming very delicate, they lose themselves in the pulp of the spleen in the manner previously mentioned. The thickness of a sheath is always less than that of the coat of the artery which it incloses, and greater than that of the vein; yet this does not hold good of vessels in all parts of their extent, since on the finest branches the sheaths are proportionally somewhat stronger than on the larger ones. As to the relations of the sheaths to the rest of the spleen substance, it must especially be considered that they do not lie free in the parenchyma of the organ, but are connected with the general trabecular network by means of balks which are given off from them: but these balks are not so numerous as different anatomists appear to think; so that we are scarcely entitled to consider with Giesker, that the whole trabecular network is formed out of this connection.

In other Mammalia, as in the horse, ass, ox, pig, sheep, &c., the course of these sheaths differs in some respects from that seen in man. In the three latter animals, which in this respect are best known to me, no

* On the Structure and Uses of the Spleen, Phil. Trans. for 1808.

sheaths at all are found on the smaller veins, and on the larger they are chiefly found on that side on which the arteries and nerves which accompany them lie. Only the two primary trunks of the veins which proceed from the spleen have for a very short distance a complete sheath, while all the arteries, even the finest, possess one; a condition of which more will be said hereafter.

The minute structure of the sheaths of the vessels in man altogether correspond with that of the partitions; and this holds good of animals generally. But I have not been able to detect unstriped muscular fibre in the sheaths in all those cases in which I have found it in the trabeculæ. In oxen this is especially the case; while, on the contrary, in pigs, &c., they are very plainly present.

Great difficulties oppose the inquiry concerning the distribution of the vessels in the spleen itself: since, 1stly, injection or inflation of the vessels gives little result on account of the delicacy of the organ; and, 2dly, great difficulties are connected with the microscopic examination of the organ. What will be now adduced concerning it is especially the result of the latter method of inquiry, which, combined with fine preparations by the knife, has seemed to me to be the most fertile in results.

When the main branches of the splenic artery have entered into the spleen they lie in their sheaths, each in company with a vein, to which they are posterior and inferior: they are in tolerably loose connection with the sheath, and not unfrequently they take a serpentine course. In their further distribution they do not behave as arteries generally do, which continually give off smaller branches, but they divide immediately into a quantity of different large and long branches in the manner of a shrub; of these the larger branches go to the anterior, the smaller to the posterior, margin of the organ. Beside this, it is especially to be remarked of the arteries of the spleen, that their different branches form no anastomoses. Assolant tied a branch of the splenic artery in a living dog, and then allowed the spleen to return into the cavity of the belly. The dog died thirty hours after: much inflammation and exsudation of a bloody serous fluid was found in the belly, and the spleen was quite healthy; only the part cut off from the circulation of the blood was gangrenous, and, as it were, separated from the sound part by a line of demarcation. In contrast to this, Heusinger tied all the branches of the splenic artery, one only excepted; upon dissection, the whole spleen was found to be mortified, excepting the part in which the artery not deligated ramified. Also injections in an artery always return solely by the corresponding branch of vein; and they only fill that region of the spleen in which the branch ramifies, never passing over into any other. I am unable from my own experience to pass any judgment upon these data, and will therefore not impugn them; but I may be allowed to doubt whether the capillaries of the pulp are completely separated from each other, and am more inclined to believe that, in consequence of the anatomical circumstances of the pulp, such a separation must be considered as impossible; since in the spleen we have before us, not a gland with special lobes separated from each other, but a parenchyma everywhere united. The above results of deligation and injection by no means necessarily imply an isolated course of the capillaries, and are fully explained by the supposition that the arteries possess no anastomoses.

When the arteries have divided into small vessels of 1 to 2-100ths of a line, they come into contact with the Malpighian corpuscles in the mode already described; while they are also connected to these by their sheaths. According to Giesker, their final terminations are coronal or pencil-shaped, radiating so as to surround the Malpighian corpuscles, and altogether enclose them; then arriving at the highest point of the vesicle, they return upon themselves in the shape of a loop, course back again as veins, and there meet together, beneath the point whence the artery radiated, to form a vein, which enters the same sheath from which the artery emerged. At this point the sheath divides into three to four fibrous threads, which pass over on the spleen corpuscles to the threads arising nearest to them, and unite with these. If we compare with this description of the minute anatomy of the spleen that which is considered most admissible by J. Müller, the next author after Giesker, we shall find very considerable contradictions. J. Müller finds that the smallest branches of arteries partly continue on the side of the corpuscles without giving off branches to them, partly perforate either a portion or the whole of the corpuscle, without in any instance leaving any branches of the artery in its interior; that these fine arterial branches pass through the middle of the corpuscles, then continue on their coats, and then quit them altogether; and that if an artery in the corpuscle divides into many branches—which never happens on the surface, but always in the thickness of its coats — these branches leave it again, in order to ramify minutely in the surrounding red pulpy substance of the spleen, into which part especially all the fine pencil-shaped ramifications of the arteries pass. The commencements of the veins spring from these branches; they are tolerably large, anastomose frequently with each other, and scarcely have a special coat as yet. If a little piece of the pulp of the spleen be carefully examined, it will be seen that it is as if cribriform, and constitutes as it were a network of red partitions, the diameters of which are larger than the interspaces and canals existing between them. It is these venous canals which give the cellular appearance seen in inflation of the veins of the pulp, and which, injected, form structures resembling the corpora cavernosa of the penis. Special cells or cavities do not exist.

So far J. Müller. If we now ask ourselves the reason of these important differences between these two authors cited, one of whom affirms the continuation of the tufts in the pulp, and a connection of Malpighian corpuscles with arteries and venous interstices only; while the other denies all this, we shall find it not very difficult to give an answer. Giesker, in his description, limited himself to the appearances met with in the human subject, while J. Müller made the pig and the ox the basis of his delineation. This circumstance will at least partially explain the want of correspondence in the two descriptions; for I find that between the spleen of man and that of the animals mentioned considerable differences exist.

In *man*, at least generally, the arteries together with the veins pass deeply into the substance of the spleen, lying in the same sheath with them, and exactly following their course. According to Giesker, the two classes of vessels accompany each other even to their final ramifications; but this is not correct. In every spleen instances occur, which are easily seen, where small veins and arteries lie very close to each other; and Giesker has evidently allowed himself to regard these particular instances as the rule, and has extended it as a description to the smallest branches of vessels. But if an arterial and venous primary branch be successively followed to their minutest ramifications, it will be seen that, sooner or later, every artery and vein, without exception, separate from each other, and follow their special path. It is not at all unusual to find this even with arteries from ½ to 1 line in diameter, but it is always the case with those of from 1-10th of a line. In such an instance the artery, setting out alone, does not perforate the sheath in which it hitherto lay, but takes with it a distinct yet often inseparable covering of the same; so that from this point forwards a special and separate venous and arterial sheath exist. And in man the Malpighian corpuscles lie only on these isolated arteries; a state which Malpighi and Müller had already described in Mammalia.

As regards the other circumstances of the arteries, I have found them exactly as Müller describes them in the lower animals. After the smaller branches of the arteries are connected with the Malpighian corpuscles, they enter into the red spleen substance, and immediately upon this each small trunk spreads out in the shape of a tuft into a large number of yet finer arteries (*fig.* 526, *d.*); and these tufts or pencils of arteries, lying in great numbers close to each other, give to the terminations of the arterial trunks a very beautiful appearance, which may be best compared to the broad crown of a (*pollard*) tree. These separate tufts, dividing and diminishing in size yet more, terminate by an immediate transition into the true capillaries; which, in a more and most minute form of 3 to 5-1000ths of a line, constitute a close and beautiful network in the separate portions of the pulp, and in those parts of it which surround the Malpighian corpuscles; although they do not form a special vascular covering for the same. Many authors seem to deny the existence of capillaries in the spleen: thus Engel * has lately altogether denied them; but this is quite erroneous. They may easily be seen in the pulp of the human spleen, by the aid of the microscope, both empty and filled with blood, and exhibit themselves as in no way different from the capillaries of other organs; and the finest of them have a diameter of only 3-1000ths of a line. J. Müller is also in error when he describes the arteries as coursing through the coats of the Malpighian corpuscle, since they always pass on its exterior. Finally, Giesker is wrong in describing the arterial pencils as spreading themselves out on the Malpighian corpuscle, and here becoming continuous with the veins; even in man it is not difficult to discover that the pencils only begin beyond the corpuscles, that they lie in the pulp, and that it is here they first break up into capillaries.

Giesker at least partially agrees with this statement when he says † that the pulp consists of nothing but the minutest arteries and veins united by fibrous tissue. The sheaths of the vessels above described are just as much more delicate as are the vessels themselves, and they are finally lost as distinct coats on the capillaries; here they form delicate fibrous membranes which connect the capillaries together, and under this form they pass through the whole of the pulp.

As to the *veins*, I must first, with Giesker, express myself in the most decided manner against all the more ancient and modern anatomists who suppose and describe venous spaces (*sinus venosi*) in the human spleen. I have bestowed the greatest attention to the dilated commencements of the veins in question, and it was only my own researches that led me to renounce the opinion that these dilatations really exist; indeed I have never been able to discover anything special or extraordinary about these veins. Firstly, as to the larger veins, which are as yet accompanied by the arteries, there is nothing very remarkable about them, with the exception of their considerable size, which has been already mentioned. They all have a membrane which is continuous with that of the smaller veins, and is least separable on that side with which the artery is in contact; this membrane is only distinguishable from the sheath of the vessels by its greater delicacy, and in company with this sheath it gradually diminishes its thickness. Orifices of the smaller veins, constituting the so-called stigmata Malpighi, are present in very small numbers in the larger veins; while, on the other hand, they are somewhat more frequent in the smaller of the vessels in question. When the veins

* Zeitschrift der Gesellschaft der Aerzte in Wien, 1847.

† Loc. cit. S. 166.

leave the arteries and pursue their way alone, they vary in some respects from this description, although not so considerably as might be imagined from the delineations which have been given of them. In the first place, the character of the branchings is peculiar, since from hence onwards, and so much the more frequently the smaller the veins become, branches are given off from the veins on all sides at very nearly right angles, and the open mouths of these ramifications are seen from within as numerous round or oval orifices lying very closely to each other. In the second place, the membranes of these veins gradually become thinner and thinner, and at the same time are blended with the similarly attenuated sheaths, so that both constitute only one delicate membrane, which is nevertheless everywhere demonstrable even in the smallest vessels which can be isolated, and which everywhere exhibits itself without any interruption as a perfectly continuous membrane. Dilatations or pouchings can nowhere be seen, either in the course of the isolated veins or in their smallest branches; only it must be added, that the narrowing of their calibre occurs much more slowly than in the arteries. As to the beginnings of the veins, and their connection with the capillaries, I have not been able to detect anything more than what one sees elsewhere; namely, that by a constant simplification and attenuation of their structure, the veins finally pass into capillaries. Here also no traces of dilatations are visible, of whatever kind these dilatations might be imagined to be; and there is just as little appearance of any other peculiarity.

As regards *the brute mammalia*, many of them certainly correspond in a very considerable degree with man, in respect of the condition of these vessels; but my researches do not extend sufficiently to enable me to express myself decisively on this point. While, on the other hand, some, as the horse, ass, ox, pig, and sheep, exhibit essential differences. In the latter animal, which I have examined the most carefully, the following deviations are present. The arteries differ little from those of man, only they separate earlier from the veins to pursue their isolated course. In most other respects they behave precisely as J. Müller has described them, and as I have also spoken of them in man; only I cannot corroborate the statement of Müller, that the sheaths of the smaller arteries are equal in strength to those of the greater. The ramifications which reach the Malpighian corpuscles measure from 1 to 1½-100ths of a line in diameter; they then course in the pulp, form very beautiful tufts, and finally capillaries, of which the smallest measure from 3 to 4-1000ths of a line. But in contrast to this, the veins exhibit very essential differences. In the first place, a special membrane and sheath are only found in the largest venous trunks, and even here they only extend a short distance around the circumference of the vessel; while more deeply in the spleen they only lie upon the side where the artery and nerve are attached to the vein. In all the smaller veins which are no longer accompanied by arteries, there is no trace of these two membranes to be seen; and not only is this the case, but the mode in which the precise limit of the venous canal is indicated is also very extraordinary. The vein appears to be formed in the first instance by the strong anastomosing trabeculæ, and soon afterwards it seems composed simply of delicate fibres and red substance deposited between them, a structure which continues even into the large venous trunks. They thus distinguish themselves at the first glance as excavations in the parenchyma of the spleen, which are devoid of walls. Nevertheless, by a more careful examination of the red limits of these veins, one may verify their smooth and shining appearances, a circumstance which is significant of the existence of a delicate membranous covering; and, in point of fact, microscopic investigation proves the existence of an epithe-

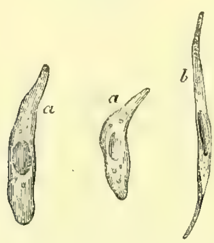
Fig. 534.

Epithelial cells from the Splenic vein of Man and other Mammalia. Magnified 350 *diameters.*

lium, which every where clothes this surface, and consists of fusiform or more spherical cells, of ½ to 1-100th of a line in diameter, with roundish or elongated nuclei of 3 to 5-1000ths of a line in size (*fig.* 534.). This epithelium altogether corresponds with that which covers the part of the veins possessing a visible membrane; but in the vessels of which I am speaking, it is placed in part immediately on the trabeculæ, in part upon a delicate fibrous membrane limiting that part of the pulp which bounds the veins. In consequence of what has been said, the greater number of the splenic veins of the ox must be likened in respect of their structure to the spaces in the corpora cavernosa penis, and to the sinuses of the dura mater; since, instead of the venous membranes elsewhere present, they possess only the "*tunica intima*" in the shape of a delicate epithelium. So that one may speak of them as "*venous sinuses*," and the more correctly, if it be considered that these veins, almost devoid of walls, possess a colossal width, and are everywhere rendered quite cribriform by larger and smaller veins opening into their interior; which smaller veins may themselves be traced by their great width for a considerable distance. How these smaller veins are connected with the very distinct capillary network of the pulp, I have not been able to find out; and I do not believe that either injection or inflation of the vein, or a microscopic examination, will ever give any definite conclusion hereto. For these vessels, often possessing but a few little trabeculæ for their coats, are of such a delicate texture, that they tear by the slightest mechanical force, while by the microscope they cannot be distinguished from the surrounding constituents of the pulp. Yet thus much one may see, that the veins gradually become very small,—so small, that it is quite impossible to talk of their commencing as dilated spaces. For my own part, I am convinced that a similar communication obtains between the veins and capillaries of oxen as of men; and that the only possible difference is, that the veins here possess only an epithelium, and must therefore be connected with the capillaries in a somewhat different way. I will yet further add, that in microscopic examination of the pulp of animals, skeins of epithelium are not unfrequently found, consisting of roundish cells, as it were, fused together: these can only come from the small venous trunks.

The following may be noticed concerning the microscropic structure of the splenic vessels: —The arteries everywhere possess their three usual coats. The *inner* consists, first, of an

Fig. 535.



Epithelial cells from the human Splenic artery. *a*, shorter cells; *b*, somewhat longer cells.

epithelium of spindle-shaped cells, which easily come off in skeins or separately (*fig.* 535, *a*, *b*); and, secondly, of an elastic membrane of homogeneous composition, wrinkled in the longitudinal direction (*fig.* 528, *e.*), and with or without openings: which openings although very small, are visible even in the arteries of the tufts. The middle tunic is very thick, and gives rise to the considerable thickness of the wall of the vessel; it contains very little else but unstriped muscular fibres. In the larger and largest arteries, nets of elastic fibre and elastic membrane (*gefenstirte membranen* of Henle) are also present, while they exist without exception on the vessels which pass to the Malpighian corpuscles, and on those which form the pencils or tufts. The adventitious (or cellular) coat is altogether absent from the smaller vessels in the interior of the spleen, and is here represented by the sheath; but it exists in the larger vessels, and presents white fibrous tissue and meshes of elastic fibres. The capillaries (*fig.* 536.) have a simple, structureless membrane, with nuclei lying on its

Fig. 536.

Capillary from the Spleen of the Pig. Magnified 350 *diameters.*

inner surface. The veins have been already described as they exist in brute mammalia: in man they possess—1. An epithelium as above described; 2. A membrane of elastic longitudinal fibres; 3. Transverse unstriped muscular fibres, in a single or double layer, which are present in the trunk of the splenic vein and all its primary branches in the interior of the spleen, but are absent from the smaller and smallest veins; 4. White fibrous tissue, with elastic fibres which take a longitudinal direction. The smallest veins possess only white fibrous tissue with elastic fibres, and an epithelium.

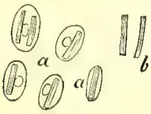
So much has been already said above concerning the blood of the splenic vessels and of the spleen, that I will here only append some special observations made upon animals. In a dog whose spleen abounded in the dissolving blood globules, the blood of the splenic vein distinguished itself by a very great quantity of colourless blood corpuscles, almost all of which contained numerous nuclei, and often had a deceptive resemblance to pus globules. In the blood of the liver were found a great number of altogether different blood

Fig. 537.

Blood corpuscles from the liver and Splenic vein of a Dog, with yellow crystals of a substance resembling Hæmatine.

globules (*fig.* 537.). These were swollen out and almost colorless, but contained from 1 to 5 thinner or thicker small rods of a dark yellow colour; part of these possessed the same length as the blood globules, part were shorter. These small rods were unchanged in water, but in acetic acid they seemed to disappear. In a second dog I found the same cells with small yellow rods in the blood of the splenic vein, while they could not be detected in any other part of the body. With them I found at the same time numerous colourless blood globules with manifold nuclei. In the fresh-water perch, the blood of the splenic vein of many individuals contained numerous golden yellow cells with diminished blood globules. In the same blood, and in the splenic pulp, there also occurred, either sparingly or in uncommon quantity, rod-shaped crystalline corpuscles, of a yellow colour, and a length of 4 to 6-1000ths of a line : at the first glance they seemed to be lying altogether free, and they were dissolved by potash (*fig.* 538, *b*). On the application of water a membrane was upraised from these

Fig. 538.



Similar blood corpuscles from the Spleen and Splenic vein of the fresh-water Perch.

a, crystals and nuclei seen on treating colourless nucleated blood corpuscles with water; *b*, crystals apparently free.

small rods, and near them a nucleus came into view (*fig.* 538, *a*). On more accurate inquiry, it plainly appeared that these small rods lie in decolorized blood globules, and in unchanged blood globules the gradual formation of one, or even two, of these may be followed. In *Barbus fluviatilis*, the spleen pulp contains an enormous quantity of really free crystals; these are of a violet and reddish colour, and of a nail or spindle-shaped form ; and on the application of acetic acid, they are completely dissolved, leaving some colour behind. Crystals such as these also occurred sparingly in the kidneys, the liver, and the blood of the heart. In this animal, as well as in *Cyprinus brama*, the blood contained yellow granule-cells, like those which occur in the spleen and kidneys. All the rod-shaped yellow corpuscles just named (of which the first, indeed, are nothing but crystals) must in any case consist of a substance allied to the hæmatin of the blood ; and possibly they consist of the substance which Virchow has lately named hæmatoidin, with which they correspond in some respects. Their occurrence in the spleen is physiologically interesting, and so also is their formation within the blood corpuscles, while at the same time it affords a very plain indication of the relation of hæmatin to them.

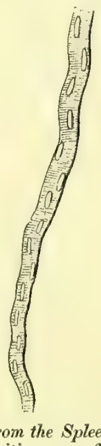
7. *Lymphatics.*—The views of authors concerning the lymphatics of the spleen are very contradictory, since one class have the precedent of Haller for altogether denying their existence in the human spleen, while others have stated their existence in abundance, and have constituted the spleen, in a certain measure, a large lymphatic ganglion. This difference mainly depends hereon,—that the one class have specially examined the human spleen, while others have chiefly drawn their conclusions from that of the lower animals, considerable differences in respect of these vessels existing in different creatures. In man, the lymphatics of the spleen are, at any rate, in utterly inconsiderable quantity, being rather less numerous than in other glandular organs, as the liver and kidneys, and not at all so numerous as in the lymphatic glands. They are divisible into superficial and deep. The former course, in sparing numbers, between the two coats of the spleen, and form in this situation delicate trunks, which anastomose with each other ; but, excepting in perfectly healthy spleens, and *in the neighbourhood of the hilus*, they can scarcely be recognised. The latter lie in sparing numbers in the hilus, and in the sheaths of the vessels, where they accompany the arteries, although they cannot be traced so far as there. Both sets of these vessels pass to the gastro-splenic omentum, to enter the small lymphatic glands placed there ; and finally they collect to a trunk which opens into the thoracic duct, at about the eleventh or twelfth dorsal vertebra. All these lymphatic vessels can only be thus seen in the quite fresh and undeteriorated spleens of executed criminals or subjects killed by accidents, although they may often be recognised in particular parts of the healthy spleen after natural death, especially if the vessels be tied and the spleen soaked in water. But, on the other hand, in diseased spleens it is very rare to see even a trace of them, unless a preparation be made of a small gland in the gastro-splenic ligament, in which case small entering and emerging trunks may be recognised.

In the lower animals, or at least in many of them, the lymphatics seem to be more numerous. Moreschi distended the lymphatics of the spleen in fishes (in whom they possess no valves) from the trunk, and he says that the injected spleen appeared to consist almost solely of a network of absorbents. But in another place he freely states that the spleen consists, so to speak, of nothing but vessels. In a *Testudo mydas*, Tiedemann and Gmelin saw all the absorbents of the small intestine going to the spleen, in which, by interlacing with arteries and veins, they formed a network. From this network large branches, like the emergent vessels of the lymphatic glands, took their course towards the thoracic duct. Almost all the older writers recognised the richness of the spleen in lymphatics, which later examiners have but confirmed. But it will be well to set forth one fact which, in my opinion, is not sufficiently estimated, namely that *even here* absorbents are *only sparingly present in the interior of the spleen ;* at least I have found this to be the case in the pig, ox, sheep, &c. Here the superficial lymphatics are, as is well known, very numerous, and this fact seems to me to correspond with the circumstance that in these animals the serous and fibrous coats are only loosely connected to each other, and contain many vessels in the loose areolar tissue between them. But, on the other hand, if the vessels in the hilus be examined, only a few scattered trunks can be seen, a condition which stands in extraordinary contrast with the very numerous lymphatics of the coats. Thus, for instance, in the hilus of a large calf I found only four trunks of lymphatics, which together possessed a diameter of only 176-1000ths of a line; while the interior of the spleen is also poor in lymphatics, for, so far as I have seen, the numerous plexuses of lymphatic trunks in the coats of the spleen have no relation with the interior of the organ, but at least the greater number of them belong solely to the subserous areolar tissue.

As to the distribution of the lymphatics in the spleen, it may easily be seen, by observations on oxen, that they only follow the course of the arteries, lying with these inside the sheaths; while the veins, which take a solitary course, and (as was before mentioned) possess no sheath, are also devoid of these companions. I have not seen the commencement of the lymphatics, yet I can state for a certainty, that they have nothing to do with the Malpighian corpuscles, since these corpuscles are completely closed, as was before mentioned. And, I will add, in support of this my view, that the small arteries which pass to the Malpighian corpuscles are no longer accompanied by lymphatic vessels; at least microscopic examination detects no trace of such vessels within their sheaths. Just as little does the pulp possess any lymphatics; for if these, like the nerves (see below), pass from the sheaths of the arteries into the pulp, they would in such a case be visible. And from what has been said, I conclude that the lymphatic vessels of the interior of the spleen belong wholly and solely to the sheaths of the arteries, and not in the least to the pulp or the Malpighian corpuscles; and thus that here they play precisely the same rather subordinate part which they do in the liver, where they pertain to the capsule of Glisson, and not to the glandular substance; or as in the kidneys, in the interior of which they only accompany the bloodvessels. Concerning the structure of the lymphatic vessels, I can only state thus much; that in the calf they possess, at least in their main trunks, three membranes: — 1. An epithelium similar to that of the arteries; 2. A circular fibrous membrane, composed of two or three layers of very distinct unstriped muscular fibres; 3. An outer membrane of white fibrous tissue. Valves occur in the deep as well as in the superficial lymphatics.

8. *Nerves.* — The nerves of the spleen arise from the splenic plexus, and accompany the splenic artery as two or three interlacing trunks, and divide in such wise at the giving off of its branches, that each artery receives one, or very frequently two nerves, which accompany it, and here and there anastomose with each other. The thickness of the primary nervous trunks varies very much in different creatures. Thus in the sheep, and especially in the ox, they are of really a colossal size, and taken all together, their diameter equals that of the empty and contracted splenic arteries; while in man and the pig they are no way remarkable in size, and are many times smaller than the arteries. These differences, which led the earlier authors to speak of the splenic nerves in similarly different expressions, were at first altogether inexplicable to me, since I could not understand why the spleen of one animal should possess so much larger nerves than another. On a more careful examination, the microscope gave a very simple and unforeseen explanation. The uncommon size of the splenic nerves of Ruminantia depends solely on this, — that the white fibrous tissue of these nerves is disproportionally developed in the shape of the so-called "fibres of Remak," while it is much less prominent in the same nerves of other animals. A comparison of the splenic nerves of the pig and calf has taught me that if we limit our inquiry to the number of primitive nerve fibres, scarce any difference exists between the two sets of nerves. But, on the other hand, the primitive nerve fibres of the pig lie very closely together, so that they cannot be numbered without considerable trouble; while as an example of their condition in the calf, I will adduce the following: — The trunks of the nerves entering the hilus were seven in number, with a diameter of ·57, ·2, ·048, ·6, ·48, ·48, ·6 (line); and they contained respectively only 28, 7, 6, 9, 13, 9, 22 primitive nerve fibres. In the lower animals, the nerves may be followed with the knife for a considerable distance into the spleen, much further than in man; and with the help of the microscope, I have very frequently followed them even on the arteries which go to the Malpighian corpuscles. I have been just as little able as Remak to find any ganglia on the arteries in the interior of the spleen. Concerning their mode of termination, I am only able to say thus much; that the nerves also pass into the pulp, and may even be easily seen on the pencils of arteries, and finally that they disappear as very small branches of not greater size than the smallest capillaries; but I am unable to decide whether they terminate by means of

Fig. 539.



A very small nerve from the Spleen of the Calf, without any visible primitive nerve fibres, and apparently consisting only of neurilemma (or fibres of Remak). Magnified 350 *diameters.*

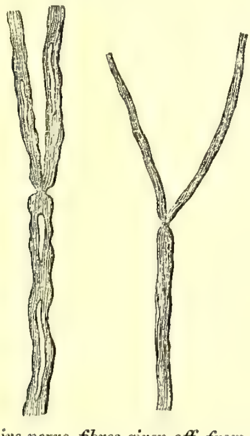
loops or with free extremities. In the calf, the thickness of these smallest nerves on arteries of a line in diameter (where it is not uncommon to find two such trunks) is 24 to 28-1000ths of a line; on the pencils of arteries 48 to 56-10,000ths; on the smallest arteries and capillaries 3 to 4-1000ths. Their structure was so far peculiar, that in the calf the finest nerves (*fig.* 539.) exhibited no trace of nerve fibres, even when treated with soda and acetic acid, but they seemed to consist wholly and solely of the fibres of Remak. Nevertheless, in branches of 12 to 28-1000ths of a line, I have often very plainly seen a single

Fig. 540.

A somewhat larger nerve, in which may be seen a single dark nerve fibre: also from the Calf. Magnified 350 *diameters.*

nerve tubule of 20 to 28-10,000ths of a line (*fig.* 540.), with dark margins, in the midst of the fibres of Remak. From these facts it may be concluded that the finest nerve tubes in the spleen of the calf are devoid of the dark borders, just as they are in the organ of smell according to Todd and Bowman; or as in the Pacinian corpuscles, the cornea, &c.; but we are scarcely able to conclude therefrom that they possess the same constitution in the adult animal. I will here permit myself to

Fig. 541.



Two primitive nerve fibres given off from the trunk of the splenic nerve of the Calf, about an inch before its entry into the Spleen. Magnified 350 *diameters.*

add an interesting microscopic observation concerning the splenic nerves of the calf. A *division* of the *primitive nerve fibres* takes place in them (*fig.* 541.), similar to that which Henle and myself found in the Pacinian corpuscles, Müller, Brücke, and R. Wagner in the muscles, and Savi and R. Wagner in the electrical organ of the torpedo. But what is *altogether new* in the minute anatomy of nerve is, that these divisions do not take place at the terminations of the primitive nerve fibres, but *in their trunks.* I detected them in the large trunks which accompany the splenic artery previously to its entering the hilus; and, indeed, in considerable numbers, so that I often counted three or four such divisions in one preparation. They always took place by the division of a primitive nerve fibre at an acute angle into two parts, and never gave rise to more fibres. These divisions often repeated themselves on the same fibre, so that in one instance three, and in another case even four, fibres were given off by the successive divisions of a single primitive fibre: this happened in the smaller branches in the interior; but, so far as I could remark, it did not occur in the smallest branches of nerves, although, from the difficulty of examining the finer nerves, I cannot say that such divisions were absolutely wanting here. The signification of these facts seems to be very important, both in an anatomical and physiological point of view, but this is not the place to give a more detailed statement. But thus much will I remark: that by means of such a distribution of the nerves, a small nerve may be rendered subservient to a larger organ; and, in addition, an harmonious activity of the whole organ may be facilitated; while, finally, in respect to sensation, it may possibly explain the want of an exact local sensibility.

In concluding this treatise on the anatomy of the spleen, I will allow myself *briefly* to propound somewhat concerning the physiological and pathological *properties* of the organ.

The spleen is developed at the end of the second or the beginning of the third month, in the fœtal mesogastrium at the fundus of the stomach. It originates from a blastema which is developed independently in this situation, and neither proceeds from the intestine, like that of the liver, nor from the pancreas, as Arnold has maintained; since, although in the ruminants it is placed on this gland, yet in the dog, according to Bischoff, it is not. It is at first a small, white, often slightly lobulated corpuscle, which gradually reddens, and soon becomes as rich in vessels and blood as it is in the adult. The elements of the fœtal spleen are originally quite uniform cells; at a later period part of these are transformed into fibres and vessels, while part become persistent as the parenchyma-cells. It is only subsequently that the Malpighian corpuscles are developed, yet I have found them, without exception, both in man and animals, at the end of the fœtal life. According to Heusinger, the proportion of the spleen to the whole body is, in an embryo of ten weeks old, as 1 to 3000; in the eighth month it is, according to Huschke, as 1 to 720; while at birth, he states it to be as 1 to 357; in the adult as 1 to 235 to 400; and in old age as 1 to 600 to 800. From these data it will be seen, that the proportionate weight of the spleen to that of the whole body increases very rapidly in the embryo, and is almost as great at the period of birth as in the adult; from which it sufficiently follows, that the spleen is an organ, the activity of which extends from the end of the fœtal period through the whole life, and reaches its highest point in middle age.

As regards the *function* of the spleen, of the innumerable theories and hypotheses respecting it, only a very few deserve a nearer consideration; namely, only those *which place the spleen in intimate relation with the life of the blood.* In point of fact, almost all the facts which with greater or less certainty we know concerning the spleen, and, above all, the anatomical ones, point to such a relation. Hewson had already stated, that when an organ receives more blood than it requires for its own nutrition, we may conclude therefrom that that blood undergoes a change in it, or a secretory process takes place; and this expression will not apply to any organ in the body better than to the spleen, which must be considered as relatively better supplied with blood than any other organ. Therefore since all pathological, anatomical, and physiological facts prove a relation of the spleen to the blood, we may securely assume, that a change of the blood takes place in the spleen. The only difficulty is to know what change. Firstly, the blood may either suffer a change in its transition from the arteries to the veins; or, secondly, the separation of a particular lymph from the blood may take place in this organ. It is well known that the latter view was first maintained by Hewson *, who at the same time announced that the lymph generated in the spleen serves to form blood corpuscles; and since then, Tiedemann and Gmelin have specially supported the same view. But the grounds adduced for this theory seem to me to be insufficient. At one time, the great quantity of lymphatics in the spleen was brought to prove that a special lymph was developed here. But that part of the spleen on which special stress is laid, namely, the interior or parenchyma, is quite poor in lymphatic vessels; and its surface, even in the lower animals, scarce contains more of such vessels than other organs; to wit, the peritoneum covering the liver, the pleura covering the lungs, &c. Therefore the formation of a special lymph by the spleen can as little be assumed as in the case of the lungs and liver. Secondly, the red colour of the spleen-lymph, and its greater coagulability, have been adduced as proofs of a peculiarity, and of a blood-forming import. But it may be demanded, are these properties constant, and on what do they depend? As to the first question, it is certain that a red colour of the spleen-lymph is, on the whole an *exception*, as Seiler and Ficinus * formerly stated. In rabbits, cats, or dogs, I have never found such a colour, and have also always found the chyle of the thoracic duct of only different shades of white. But I will not deny that in calves and sheep a reddish spleen-lymph is often found, and I will add that this is frequently the case in the horse. But this is sometimes the case in other organs, as, for instance, in the liver and in the lacteals, where Tiedemann and Gmelin in some cases also found a reddish and very easily coagulable fluid; and it is important to observe, that the reddish colour and easy coagulability in these cases depend simply on blood which is mixed with the lymph. Thus, if the reddish spleen-lymph of a calf be examined, a quantity of fully developed blood corpuscles are found in it, which are altogether identical with those in the blood.† Now since it cannot be assumed that real coloured blood globules are formed in the lymphatic vessels of the spleen, and since, in point of fact, all trace of such a developement of blood globules is absent, it will only follow from the facts adduced, that in the cases of reddish spleen-lymph a mixture of real blood and lymph has taken place. This mixture may be the result of normal anastomoses between lymph and bloodvessels, or may owe its origin to a rupture of both these vessels. I believe the latter to be the case, and am simply of the opinion that it is not at all to be wondered at. For in Tiedemann's cases the animals were either killed by a blow on the head, or died during convulsions; and it is not surprising that during such a death-struggle an organ so richly supplied with blood as the spleen should make an abnormal path for that fluid, or that a similar thing should happen when the vena porta has been tied. It is well enough known, how easily the lymphatics of the spleen are filled by an injection into the bloodvessels. The reddish colour and easy coagulability of the spleen-lymph in particular cases therefore proves nothing at all, except that, on account of its great vascularity, blood is more easily extravasated in the spleen than elsewhere, and enters the lymphatic vessels. Thirdly and lastly, Tiedemann and Gmelin adduce the above-mentioned course of the lymphatics in the tortoise as a powerful proof of their view; but Rudolphi ‡ found exactly the contrary, since in two large sea-tortoises not a single lymphatic of the intestine passed to the spleen, but they all went directly to the thoracic duct.

In consequence of what has been said — which I might also corroborate by many other facts could I go more into detail — it is impossible to imagine the development of a special lymph in the spleen; and hence the

* Opus posthumum, sive rubrarum sanguinis particularum thymi et lienis descriptio, 1786.

* See Giesker, S. 265.

† See also Nasse, (Wagner's Handwörterbuch der Physiologie, Band ii. S. 370.)

‡ Physiologie, Band ii. Heft 2. S. 156.

theory which ascribes to the spleen a relation to the lymphatic system, and considers it as in a certain manner a large lymphatic gland, is utterly devoid of meaning. In this manner there remains as a last resource the view, that changes occur in the blood itself contained in the spleen. But what is the nature of these changes? Are blood corpuscles possibly formed in the spleen, as has been already so often supposed? Certainly not; for in the most rigorous examination of the blood in the spleen and the larger splenic vessels, just as in the spleen-lymph, no trace whatever of the formation of blood globules can be detected, much less in blood which is exactly reversed, and is exhibiting, as I might say, at every step the plainest and most lively indications of a dissolution and decomposition. Let us recall to mind the details already given of the condition of the blood globules in the spleen. Upon the facts there mentioned, in the year 1847 * I founded the conjecture that the blood corpuscles *undergo solution in the spleen, and that their colouring matter is employed in preparing the colouring matter of the bile;* a conjecture which seems to me preferable to all those which have hitherto been offered concerning the function of the spleen. If the fact be made out that new blood globules are continually arising from the cells of the chyle, it is just as certain that the blood globules must also slowly disappear in order to make room for those newly arising. And if it be considered that nobody has yet seen the least trace of a solution of blood globules in any other organ, and that, on the contrary, I have found in the spleen a healthy organ, in which, in all four classes of vertebrate animals, blood corpuscles are almost constantly undergoing decomposition, even in uncommon quantities, it will, I think, be conceded to me that I have some grounds for setting forth the hypothesis here given. It is, indeed, as yet not altogether settled whether the changes of the blood seen by me are normal or abnormal; but, as was previously remarked, so long as their pathological nature is not proved with certainty, I must continue to regard them as physiological and pertaining to healthy life. But this is not saying that they occur in all creatures in the method described above. It is highly possible that blood globules undergo dissolution in the spleen without previously forming the cells containing blood corpuscles: an opinion which is corroborated by the blood globules described above as occurring in the blood of the splenic vein of the dog and fresh-water perch: these contained crystals of hæmatine or some kindred substance, and were evidently near their destruction. Indeed, it is even possible that such a direct mode of dissolution may be the rule in some animals, perhaps even in many. And although I have regarded the spleen as an organ in which the blood corpuscles undergo dissolution, yet I have not maintained therewith that it is in all animals the *only* organ in which any thing of this kind occurs: it would therefore in no way militate against my theory if it should ever turn out that in the kidneys of fishes, the vessels of which are arranged so peculiarly, a constant and physiological solution of blood globules obtained. The following circumstances also speak for my hypothesis. That in no other way can any reasonable account be given of the changes of the blood in the spleen. Furthermore, that it elucidates the relation of the spleen to the portal system of veins; since according to it, the dissolved blood corpuscles are subservient to the formation of the bile, the colouring matter of which is so nearly allied to that of the blood. Finally, that, as will be more fully stated below, the pathological facts are proportionally in unison with it.

On all these grounds I am therefore inclined to defend the hypothesis first set forth by me of a destruction of the blood globules in the spleen; and the more so, that J. Béclard has lately maintained, that the blood of the splenic vein is always poorer in blood corpuscles than that of the other veins. He has stated this in a memoir which was laid before the Académie des Sciences in Paris on the 17th January, 1848, and published in the "Archives générales de Médicine" of October to December, 1848. Since J. Béclard's results are an important support to my hypothesis, I have permitted myself to communicate here the most important of them. Béclard has analysed the blood from the lower branch of the splenic vein, and that from the jugular vein, in fourteen dogs and two horses. In most of the instances of the analysis, (1.) the water, (2.) the blood corpuscles and fibrine, and (3.) the albumen and salts, were separated from each other; and only in the horses were the blood corpuscles and fibrine obtained separately. A deficiency of the blood globules and fibrine was always present in the splenic vein, which diminution out of a 1000 parts of blood, amounted to the following quantities in the sixteen cases.

16·54	15·94	8·51
37·11	19·67	13·06
19·43	20·80	14·91
12·82	10·88	9·40
13·92	16·06	
13·60	14·78	

On an average of the sixteen cases, the deficiency amounted to 16·08 parts. As regards the albumen, on the contrary, there was a constant increase of this constituent in all the sixteen cases, in an average of 13·02 parts. Finally, in the two analyses in which the quantity of fibrine was certified, there was the extraordinary increase in its quantity in the blood of the splenic vein of 0·3 and 0·5 parts. Béclard deduces the same conclusion from these facts which I have drawn from my microscopical examinations; namely, that the blood corpuscles normally undergo dissolution in the spleen; and I regard this conclusion as neither more nor less correctly deduced than

* Loc. cit. S. 135.

mine, for it is clear that the results of his analyses may solely depend upon this fact, that in the animals he examined, the changes which I have verified in the blood globules of the spleen, were going on in an energetic manner. If these visible changes of the blood globules, — which certainly occur in a most exquisite manner in the horse and dog,—if they be normal appearances, then is the diminution in the quantity of the blood globules, which Béclard found on analysis, also a normal phenomenon; but if not, then he only examined a blood partially deprived of its globules by stagnation and effusion. The results of chemical analysis would then only be secure, if it were at the same time shown, that there were no visible changes of the blood globules in the spleens of the animals examined. Until this takes place, Béclard's conclusion will remain, like mine, hypothetical; although this is in no way diminishing the merit of his observations, since I hold my own hypothesis as one which I am perfectly justified in propounding in the present state of our knowledge. But even if we suppose that the blood corpuscles are destroyed in the spleen, it is nevertheless a question how this dissolution is super-induced, and at what time it comes to pass. As regards the first of these points, in my writing previously mentioned I expressed the opinion, that the spleen is a contractile organ, and may, by virtue of its contractility, be able to dilate and contract itself, — to fill itself with blood, and again to expel the blood from it. In the state of filling itself with blood, a stagnation of blood occurs in the smaller vessels, perhaps even an extravasation; and in this stagnant blood, the blood globules undergo destruction, since they slowly dissolve themselves, either free or inclosed in cells. This view I still regard as correct. For, firstly, it is a matter of fact that the spleen does enlarge and diminish its size, and certainly under vital circumstances which are altogether normal. Very many of the older observers have accepted this fact; as Lieutand, Haller, Stuckeley, Rush, Clarke, Hodgkin, Home, and Dobson. This is shown by an examination of the splenic region in the living human subject (Piorry). So also it is shown by vivisection of animals, in whom I have myself seen (and especially in the dog) a very distict diminution and rounding of its outer surface. Finally, Landis *, by weighing the spleen, has recognised a distinct increase and diminution of weight. He examined at different times thirty rabbits, and finds that the average weight of the organ in five observations was:

12	hours	after eating,	0·768	grammes.†
5	„	„	·588	„
8	„	„	·548	„
24	„	„	·526	„
48	„	„	·510	„
2	„	„	·444	„

Now although it may be freely conceded that an organ like the spleen is subject to so many variations in respect of size as to render thirty observations much too small a number to afford any very definite information concerning its increase or decrease of size, it must, nevertheless, be considered, that Landis has examined the proportion of the spleen to the whole body, and to many other organs, as the stomach, liver, and kidneys, and that from this means he derived a confirmation of what the estimate of its absolute weight had previously taught; so that his observations must be regarded as a meritorious contribution to our knowledge respecting the changes of volume which the spleen experiences. We now ask, secondly, how these changes come to pass? Béclard states that the spleen enlarges and becomes filled with blood in consequence of the splenic vein being compressed by a muscular force; but the nature of this he has not stated, nor can I regard his view as correct. I believe myself to have propounded a better theory when I stated, that the spleen becomes turgescent in consequence of the relaxation of the muscular fibres which exist in its balks, coats, and vessel-sheaths; or in animals from whom these are absent, through a relaxation of the muscular fibres of the vessels themselves. A constriction of the splenic vein cannot be supposed to obtain, since the muscular fibres which it contains are but very little developed, and no other compressing force is present; while, on the contrary, we know that in all animals the splenic artery is uncommonly muscular, and that the partitions of the spleen themselves contain distinct muscular fibres. It is these muscles and no others which, according to my researches, produce the distension of the spleen; but not through their contracting together, but by their relaxation, which brings with it a distension of the vessels with blood, and a slower circulation of this fluid. The diminution in the size of the spleen occurs simply through the contraction of the muscular parts just named. Precisely in the same manner the corpora cavernosa of the penis become filled with blood by a relaxation of the muscles situated in their fibrous partitions; and become poorer in blood, and smaller in size, when the muscles again contract themselves. Of course, both here and in the spleen, the nerves play an important part in the process; probably in consequence of antagonistic relations between them and other parts of the nervous system, which at present cannot be accurately indicated. Thirdly, and finally, it may be asked, whether the blood corpuscles simply dissolve because the blood of the spleen becomes stagnant at certain times, or whether special influences are necessary to this effect? — whether the parenchyma of the spleen or the Malpighian corpuscles may not secrete a juice, a "*succus lienalis*," of which the earlier authors speak, which exerts a solvent influence on the blood corpuscles? As a kind of vague answer to this question, I have examined the parenchyma with respect to its

* Loc. cit.

† The "gramme" is $15\frac{1}{2}$ grains Troy English. (Transl.)

reaction, and have found that without exception it has an energetic *acid* reaction. This appeared to me very extraordinary, and the more so when I thought of the great quantity of blood which the organ contains; and I was already captivated by the conjecture that this acid reaction might be of great importance. But I found that litmus paper was just as much reddened by the liver and kidneys of the calf and rabbit; and, further, that the muscular substance of the heart and the muscles of the trunk have the same effect. So that this acid reaction appears to be a general phenomenon, which is probably due to the fact, that the acids lately found by Liebig in muscle (lactic and inosic acids) also occur elsewhere. At any rate since there is as yet no exact chemical analysis of the spleen, I cannot express myself concerning the import of this vigorously acid reaction of its parenchyma; although it is very conceivable, that the acid reaction does not depend on the same causes in all organs.

As regards the time at which the blood globules experience their dissolution in the spleen, nothing definite can at present be said; but my theory appears at least to presuppose, that this process especially comes to pass some time after the reception of nutriment, since I have found the spleen of the greatest size in animals at about the time of five to twelve hours after eating, the same time at which the visible changes of the blood globules were most marked. The cause of this phenomenon seems to be, that the volume of the blood is increased after each time of taking food, and especially that a great number of new cells enter from the chyle. And if an equal weight is to remain in the organism, then, on the other hand, just as many elements of the blood must be dissolved, as there have new ones entered into it; and this is exactly what happens in the spleen. Besides, I am not anxious to maintain that the spleen may not become distended, and blood globules undergo dissolution, at other times than those just mentioned; probably the conditions of the liver have also a great influence upon the events in the spleen, so that in hyperæmia of the liver, the spleen becomes also distended; and so likewise the nervous system may be interested therein. Béclard, who has also found many variations in the blood globules contained in the blood of the splenic vein, is unable to assign any definite cause for these varieties, and only remarks, that in the case of a blood rich in blood globules, the amount of these lost in the spleen was greater than in the opposite case. So that it must be left to the future to bring to light the more special relations of the dissolution of the blood globules in the spleen.

I have hitherto said nothing concerning the function of the Malpighian corpuscles of the spleen. I do not regard their function as at all a peculiar one, since (1.), in many animals, as fishes and naked amphibia, these corpuscles are absent; 2. their constituents exactly correspond with those of the parenchyma of the spleen. I believe that the parenchyma-cells and the cells of the Malpighian corpuscles play exactly the same part, although I am just as little able as my predecessors to say with certainty what this is. If they are not subservient to the formation of a special fluid which takes a part in the solution of the blood corpuscles, I should be almost inclined to ascribe to the parenchyma-cells the mechanical use of forming in the first place a soft parenchyma in which the minute vessels can extend at their pleasure; and nextly, that they, as well as the elements of the Malpighian corpuscles, are simply expressions of the fact, that the spleen, as a highly vascular organ, is everywhere permeated by a fluid which is very rich in plastic matters. At the same time, it may be imagined that all these cells elaborate the fluid in which they are soaked, and after a certain kind of assimilation, again part with it, and through the blood and lymph vessels transmit it to the general circulation. The swelling up of the Malpighian corpuscles after the use of food is quite consonant with this notion. But whether this fluid is of a peculiar nature, and of different properties from that of other organs, we can only know from future chemical researches; and then only can it be determined, whether or no we are to ascribe to it a special signification.

If the spleen be the only or even the chief organ in which blood globules undergo their dissolution, in either case the part which they enact in the organism is by no means the subordinate one which many have hitherto considered it; but one which is very *full of import*. And the results afforded by vivisections and by pathology are by no means so contradictory to this expression as they are generally maintained to be. It is true that the spleen of animals may be excised without causing their death, a fact which I have myself repeatedly witnessed; it is also certain, that men can live without spleens, or with spleens completely atrophied, or rendered functionally useless by degeneration; nay, in many cases, may live without any disturbance at all,—a circumstance which is also true of animals. But what does this prove? Nothing at all; for if the spleen fails, then indeed other organs undertake its functions, and discharge them vicariously for it. Probably in these cases the blood globules undergo dissolution in the general mass of the blood, or possibly in the liver. But if this be so, the spleen is surely not therefore devoid of import or function. With equal correctness might we say, that one kidney is superfluous, because in certain cases an hypertrophied kidney enacts the part of both; or might regard kidneys generally as devoid of import, because certain rare instances of misdevelopement are narrated, in which the skin or the thoracic glands have undertaken the excretion of the urinary constituents. If the spleen is not the only organ in which blood corpuscles undergo dissolution, it is possible that these are destroyed in some small quantity in the capillaries of all the organs of the body.

Many observers, as Lecanu and Letellier, and more recently J. Béclard, have found a diminution in the quantity of blood corpuscles in the venous blood generally, although others have denied this. If this be the case, it confirms such a supposition, and would effectually explain the results of extirpation. In any case thus much is certain, that they afford no grounds for regarding the spleen as devoid of signification. Finally, we may remark in addition, that not unfrequently extirpations of the spleen give rise to considerable disturbances, and especially of the biliary secretion; a fact which very well corresponds with my supposition that the colouring matter of the bile arises from the hæmatin set free in the spleen.

If this theory of the function of the spleen which I have set forth, which Ecker has adopted, and which J. Béclard has now confirmed, be correct, it will be able to explain the diseased conditions of the spleen and their operation on the organism. But this is at present impossible, since these conditions are much too little known to allow us to say anything even approximatively correct and secure concerning their origin and import. Therefore, instead of entering upon a discursive detail of possibilities resting upon an altogether hypothetical basis, it seems to me much more suitable, simply to indicate the points to which future observers might properly direct their special attention. It is known that the enlargements of the spleen, which constitute the most serious diseases of the organ, have a special coincidence with complaints in which either a dissolution, or some other abnormal condition of the blood is present. This is the case in typhus, typhoid cholera, pyæmia, putrid exanthemata (erysipelas, scarlatina, measles), dyscrasia of drunkards, ague, scurvy, purpura, chlorosis, acute rheumatism, acute tuberculosis, &c. May not the enlargement of the spleen possibly have a share in the production of these diseases, without being so entirely secondary as most pathologists have hitherto assumed? Is it not conceivable, that in a spleen which is enlarged and distended with blood, a destruction and dissolution of the blood globules is going on on too large a scale, so that the normal composition of the blood becomes seriously prejudiced thereby? In such a case the blood would be poorer in blood globules, but its plasma would be rich in colouring matter, and possibly at first in fibrine, as J. Béclard found it to be in his analysis. May not chlorosis or scurvy, in which a considerable diminution of the blood corpuscles has been shown to exist, possibly depend in part on the disproportionate activity of an enlarged spleen? In consequence of such a too considerable destruction of blood globules in other cases, further changes of the blood may be induced, which may then end as an overcharging of the fluid with colouring matter; to wit, with the colouring matter of the bile; or as a pyæmia or the so-called white blood. On the other hand, is it not possible, that in cases of the temporary diminution, or inflammation, or degeneration, or atrophy of the spleen, other organs may undertake its functions?—as, for instance, the liver, which, indeed, is usually hypertrophied in such cases; or the general mass of blood, a state which must again give rise to peculiar phenomena? Thus, in respect of its pathology there is much which might yet be observed, if I did not consider it more suitable to conclude with the remark, that in order to the building of a larger superstructure upon the anatomical and physiological basis here given, and in aiming at anything respecting the pathology of the organ, a deliberate, careful inquiry is above all things necessary, an inquiry in which chemical analysis, microscopical research, experiment, and pathological experience, will have to go hand in hand. For if I have perhaps been able to elucidate the spleen in many respects more correctly than my predecessors, yet this account is very far from a final termination of our knowledge, and must be regarded as nothing more than a foundation-stone for an altogether new superstructure.

Morbid Anatomy. — Variations in number and form have already been alluded to. The absence of the organ is usually or always accompanied by that of other and neighbouring viscera.

On account of the obscurity which has hitherto attached to the anatomy of the organ, its diseased conditions are little understood; and it is obvious, that until morbid conditions of the spleen are examined and classified with reference to the appearances of their several anatomical constituents, there will be little to be said under the head of morbid anatomy, besides enumerating the most prominent deviations of its bulk, colour, and consistence.

Enlargement of the spleen is, perhaps, the most common of all the outward deviations. We have already seen that, within certain and very wide limits, the size of the spleen may vary, and that these wide variations are of constant occurrence even in the healthy subject, being intimately associated with its function and that of the organ. It is, therefore, only when such enlargement becomes excessive, or is associated with an alteration of texture, or occurs in the course of some of those diseases which it is known usually to accompany, that we are justified in regarding it as essentially morbid.

The enlargement of the organ, to all outward appearance, depends mainly on the increased mass of the contained blood, and is hence sometimes called hyperæmia; and the most obvious distinction of this enlargement is into two kinds:—one in which the congestion is produced mechanically; the other, in which the determination of blood to the organ can only be accounted for on the supposition of non-mechanical causes. The former of the two classes would include the swollen spleens which occur in obstructions of the portal vein, or of the vena cava, as happens in some diseases of the liver and heart respectively.

In such instances, there is little appearance of any thing morbid beyond the increase of size. The contained blood is usually very dark, and the spleen shares the deepening of colour. By long duration, the capsule of the organ and the fibrous tissues generally, become somewhat thickened, but in other respects the texture is little altered. In the second class, in which the swelling is probably produced by a peculiar state of the blood (*dyscrasia*), and is certainly associated with a class of blood diseases, the texture of the organ is usually much altered. The size of the spleen is often astonishingly increased, so that it possesses a volume of from 100 to 300 cubic inches, and a weight of 10-20 lbs. The increase includes, besides blood, a considerable quantity of a fibrinous material, the nature of which, and its relations to the healthy organ, are at present little known. The colour and consistence are of every possible gradation; from greyish to deep brownish red, or from a soft, friable mass, to a dense, firm, and almost fibrous texture. There is a general relation of these changes to the date and duration of the swelling; thus in acute or recent cases, the organ is usually soft and of a dark colour, while by long continuance, or in chronic diseases, its consistence is greatly increased, and its colour, as well as that of the contained blood, is much paler or greyer than natural. *Atrophy* of the spleen, or slow and permanent diminution of its size, is much more infrequent than the preceding converse condition. It is associated with similar varieties of colour and consistence.

Inflammation of the spleen.—The peritoneal surface of the organ shares in the diseases of this structure generally, and an inflammation of this part of the serous membrane not unfrequently accompanies the enlargements previously mentioned. The exsudation and results are no way peculiar. Concerning inflammation of the parenchyma of the spleen little can at present be said. The large and numerous veins which it contains are liable to inflammation, the secondary being the more frequent form of phlebitis which affects them.

As regards other morbid products, organised and unorganised, the spleen offers nothing deserving a special notice.

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(*Albert Kölliker.*)*

STATISTICS, MEDICAL. — *The Statistical Method; the Numerical Method. La Méthode Numérique.* — It is to be regretted that the use of numbers in any branch of scientific inquiry should have seemed to need a special name; for the name has given rise to prejudices and misconceptions which could never have attached to the thing signified. There is no science which has not sooner or later discovered the absolute necessity of resorting to figures as measures and standards of comparison; nor is there any sufficient reason why physiology and medicine should claim an exemption denied to every other branch of human knowledge. On the contrary, they belong in an especial manner to the class of sciences which may hope to derive the greatest benefit from the use of num-

* The Editor is indebted to his friend Dr. Brinton, for the translation of the article on the normal anatomy of the spleen from the German MSS. of Professor Kölliker, and for the sketch of the abnormal anatomy.

bers; and even those persons who are most given to express doubts of the necessity or expediency of resorting to them, find themselves constrained to sanction by their own practice what they condemn in theory. This is an all-sufficient answer to those who content themselves with objecting in general terms to the employment of numbers in medical investigations. As to more minute and detailed objections, these will be found to be anticipated and disarmed by the simple consideration that they apply in reality not to the use, but to the abuse of numbers. The time has long gone by, when the absolute dependence of all science on observation and experiment could admit of question or dispute; and, as no one in the present day claims for physiology and medicine any immunity from the severe conditions which the very nature of things imposes, we are spared those appeals to authority which might formerly have been required at our hands. The absolute necessity of observation and experiment towards the improvement of the science and art of medicine, in the widest acceptation of those terms, may, therefore, be safely taken for granted. The only points upon which any serious difference of opinion or divergence of practice exists, are the degree of care and accuracy which should be brought to bear on individual observations and experiments, the properties which fit single facts to be thrown into groups or classes; the language which ought to be employed in expressing the general results of such classifications; and the number of facts which, being so grouped or classified, may be required to establish a general proposition, or to furnish an accurate test or trustworthy standard of comparison.

The human mind is so constituted, that it looks forward to an occurrence with a confidence proportioned to the number of times that it has been previously known to happen. Hence, the universal belief that all living beings will die, and that the sun will rise and set to-morrow; hence, the somewhat less sanguine expectation that quinine will cure ague, and that vaccination will either prevent or modify small-pox; hence, the little hope we have that a severe attack of Asiatic cholera will terminate favourably, and our absolute despair of the recovery of a patient seized with hydrophobia. In these, and other analogous cases, we have either the experience of all mankind in all times and places, or that of large numbers of men in addition to our own. We do not require that the individual occurrences which have created our confidence, our misgiving, or our despair, should be committed to paper, arranged in columns, and embodied in sums or averages. For practical purposes we are satisfied with our own impressions. But should a doubt be expressed, and supported by a show of reason or experience, whether vaccination possess the virtue generally attributed to it; should some new preventive measure or mode of treatment be recommended in cholera, as superior to other plans previously adopted; we ask for the specific facts which have seemed to warrant the doubts of the one party, and the recommendation of the other. If these facts are few, we naturally view them with mistrust, and are disposed to attribute them, at the best, to some coincidence; or if, being more in number, their actual amount is stated in vague and general terms, we as naturally demand the precise figures. We feel instinctively, that common and familiar words are altogether wanting in precision; that they take their meaning from the character of those who use them; that, in a word, "the *sometimes* of the cautious is the *often* of the sanguine, the *always* of the empiric, and the *never* of the sceptic; while the numbers, 1, 10, 100, 1000, have but one meaning for all mankind."

But this mistrust of vague generalities of expression, is not the only form in which the more cautious and logical spirit of modern times embodies itself. The same misgivings are felt and expressed as to the propriety of committing the facts which are to serve as the materials of our theories to the uncertain keeping of the memory. We feel that a science built up of such materials, bears to true science the same sort of relation which tradition bears to history. It may not be destitute of valuable truths and sound principles, but it must fail in that precision and delicacy of discrimination which forms the peculiar attribute of true science as of true history. The history of medicine abounds with examples of important principles of treatment, and valuable remedies discovered solely by the light of experience, based upon the mere recollection of a number of individual occurrences. In this way the efficacy of bark and arsenic in ague, of mercury in syphilis, and of iodide of potassium in certain forms of secondary disease was discovered. Indeed, it may be confidently affirmed that all our knowledge of remedies is traceable to this source; and it is probable that we shall continue to be indebted to it for all future discoveries of importance. It is the natural method of discovery, and, as such, will necessarily maintain its ground. But a very little reflection will convince us of the utter inadequacy of this method to meet the strict requirements of the science, and the ever-varying exigencies of the art of medicine. We may be able by its aid to sketch the broad outlines, and mark the salient points of a science, but we cannot hope to fill in the details with all the lights and shadows which go to make up the perfect landscape. Still less can we satisfy ourselves or others as to the real merits of disputed questions by an appeal to unwritten or loosely recorded experience. We all feel that there is no solution for our doubts short of an appeal to observations carefully and faithfully recorded, and summed up in the clear and simple language of figures. The use of mercury in syphilis, supplies us with an apt illustration of this truth. An experience, founded upon unrecorded and unnumbered occurrences, first recommended this remedy for the treatment of that disease; but it would appear that a counter experience of the same kind was continually leading to its disuse. Thus Morgagni tells us that, when he was quite a young man and went to Bologna, both methods of using mercury, internal and external, were so far deserted, that he never saw any physician make use of them, or ever heard of his using them, for the whole space of eight years, during which he studied there.* It would also appear that from the beginning of the sixteenth century up to the present time, there has always been a large number of surgeons, who have either abandoned the mercurial treatment altogether, or have restricted the use of the mineral to certain exceptional cases.† In the difference of opinion which prevailed upon this subject, the necessity of submitting the question at issue to the test of figures made itself so strongly felt, that a series of the most elaborate inquiries was undertaken at the instigation of governments, or by private individuals. These inquiries resulted in the collection of nearly 80,000 facts, by means of which the possibility of promptly healing venereal sores without mercury and with but moderate risk of a relapse, or of the occurrence of secondary symptoms, was conclusively established.‡ To this same test of figures, all the questions which arise from time to time, as to the relative value of the several remedies recommended in the treatment of syphilis are, by common consent, submitted. A most convincing proof that the numerical method is, in all cases of doubt and difficulty, the means of solution to which men naturally resort, is afforded by the treatise of Benjamin Bell, on this very subject, published in the year 1793.§ Speaking of the treatment of incipient chancres by caustic, he notices the very important objection, that the cure of the sores was often succeeded by buboes; and he adds, that for a considerable time he was induced to suppose that the swellings of the glands, which thus take place after the cure of chancres, were more the effect of accident than of the method of treatment, and that they would have occurred under whatever management the sores might have been. The frequency, however, of their appearance, led him at last to suspect that he was mistaken, and further observation made it obvious that this was the case. He goes on to observe, "As experiment alone could determine the question, I was resolved to employ this test. Of the first twenty patients who occurred with incipient chancres, in ten they were destroyed by an immediate and effectual application of lunar caustic, the remedy being employed, according to my usual custom at that time, instantly on my being called; of the other ten, five were dressed with blue mercurial ointment, and five with common wax ointment. The sores to which caustic were applied healed much sooner than the others, and next to them the sores that were dressed with mercurial ointment. But of the ten patients to whom caustic was applied, no less than eight had buboes, whilst only one bubo occurred in all the others; and it happened in one of the patients whose chancres had been dressed with mercury. I thought also that buboes appeared to be less frequent from the application of caustic, where mercury had been previously given. This fell within my observation from time to time, with patients who had taken mercury, either of their own accord or by the advice of others; and appearing to be of importance, I was resolved to bring it likewise to the test of experiment, and the result was as follows: of forty-eight patients with chancres in an incipient state, and exactly as they occurred in practice, one half was treated in the manner I have mentioned, by destroying the chancres with caustic immediately on my being desired to see them, while all the others were put under mercury for eight or ten days before the application of caustic. In every other circumstance the method of treatment was the same. The difference, however, surprised me exceedingly. Of the twenty-four treated with the immediate application of caustic, twenty were seized with buboes; while only three buboes occurred in an equal number to whom mercury had been previously administered."

The subject of the treatment of syphilis has been selected for illustration on account of the large use which has been made of figures in discussing the relative value of the two modes of treatment; and the extract from the works of Benjamin Bell as a proof that, long anterior to any discussions among medical men as to the value of the numerical method and the extent to which it might be applied in the solution of medical questions, men of shrewd common sense were driven to the use of numbers, as the natural and only means of solving difficult questions, and setting doubtful or disputed points at rest. Thus much, by way of introduction, the difference of opinion which prevails as to the value of the numerical method seemed to demand.

The numerical or statistical method may be defined as the science which prescribes rules for the bringing together of scattered observations, arranging them in classes, testing their sufficiency in point of number, and deducing from them, when so arranged, average and extreme results, fitted by their very condensation to become standards of comparison and data for reasoning.

The numerical method*, so defined and

* Morgagni's 58th Epistle.

† See on this subject, the British and Foreign Medical Review, vol. v. p. 4.

‡ British and Foreign Medical Review, vol. v. p. 7.

§ A Treatise on Gonorrhœa Virulenta, and Lues Venerea. By Benjamin Bell, vol. ii. p. 322.

* The term, *numerical method*, will be used throughout this article in preference to the word *statistics*, or *statistical method*; for, properly speaking, statistics means the science of states (from the German word *staat*, a state), and is therefore synonymous with the terms "political economy," "political science," "social science." The first use of the term statistics has been traced to Achenwal, Professor of History in Göttingen, who, in 1749, published an historical work, in which the phrase *scientia statistica* occurs for the first time. The use

understood, comprises two distinct inquiries, the one relating to the individual facts which form the materials for the calculation of average and extreme values, and the other referring to the averages and extremes themselves. This natural and convenient division of the subject it is proposed now to adopt.

1. *Of facts considered as the elements of statistical inquiries.* — Scientific inquiries are conversant with two orders of facts: — namely, phenomena of varying intensity, and events brought about by a multitude of causes. The first class of facts enters very largely into the science of physiology; the last class constitutes, though not to the exclusion of the first, the mass of the materials by which the practical sciences of medicine and hygiene are built up.

As examples of *phenomena of varying intensity* may be cited the pulse and respiration, the temperature of the body, the secretions of the skin, kidneys, and lungs, the evacuations of the bowels, the weight and stature of the body at different ages, and the muscular development and power of different nations and classes of persons. These phenomena, carefully observed and recorded by the aid of the watch, the thermometer, the measure, the balance, and other instruments adapted to special purposes, become so many numerical values, having the same relation to the averages deduced from them, as the more simple events expressed in units bear to the mean results for which they furnish the materials.

As an example of *an event brought about by a multitude of causes* may be mentioned the event of death, governed, as to the age at which it occurs, by original strength or peculiarity of constitution, good or bad nursing and management in infancy, sex, occupation and habits of life, climate and place of abode, skilful or unskilful treatment in sickness; in a word, by the varied influences which make one man to differ physically from another. This is an illustration taken from the science of hygiene. The alternative of death or recovery from a disease induced by a cause or causes of variable intensity in persons of opposite sex and of different ages, with constitutions modified by the several agencies just specified, and submitted to different modes of treatment, is an example from the practice of medicine. Physiology furnishes illustrations of the same kind in those functions of the body (such as the cutting of the teeth, and the first appearance and cessation of the catamenia) which are dependent for the period of their occurrence on peculiarity of constitution determined by the combined action of the influences already adverted to.

Between these two orders of facts — phenomena of varying intensity, and events brought about by a multitude of causes — there is no other difference but that which is apparent on the face of each, namely, that each individual fact, in the one case, is represented by a variable number, while in the other it is a simple unit. If, for example, we count the pulse of several men at the same age, we shall find that each separate observation gives a different number; but, the event of death or recovery in cases of typhus fever will be recorded as a simple unit. In all other respects the two classes of facts closely resemble each other; for the number of beats peculiar to the pulse of each individual, is as much the result of the concurrent action of several causes, as the event of death or recovery from fever. The original and acquired constitution, towards the formation of which so many causes must have conspired, determines the number of the pulse in the one case, and influences the event of the disease in the other. The two classes of facts are also equally fitted to supply the elements for the determination of average and extreme values; for it is obvious that the mean and extreme numbers of the pulse, in males and females respectively, furnish as trustworthy standards of comparison and data for reasoning, as the average number of men following different occupations who die before any specified period of life, and the greatest age which they respectively attain.

From what has been just stated, it will be seen that all the facts which form the materials for our averages, are phenomena or events brought about by the concurrent action of a multitude of causes. The facts or events with which the physiologist and physician are conversant, are remarkable for the multiplicity of the causes which conspire to produce them. The subject of study is the human frame, with its differences of sex, age, and inherited or acquired constitution, acted upon by the variable influences of climate, occupation, and habits of life, and still further modified in disease by the treatment and regimen which may happen to be adopted. In consequence of the number and diversity of the influences brought to bear upon it, the human frame presents an object of study only less difficult than the human mind, affected by a like number and variety of moral causes, of which the true nature and force have to be unravelled by multiplied observations on the condition of mankind under different circumstances; the aggregate of such observations constituting a great part of the science of statistics properly so called, and bearing to the practical science of government the same relation which pathology and therapeutics, based upon large collections of facts, do to the practice of medicine.

Now this dependence of the individual facts or events with which physiology and medicine are conversant on the concurrent action of a

of numbers as a necessary means of comparison in this work of Achenwal, led men to confound the instrument with the science. Dufau, in his Traité de Statistique, incorrectly derives the term statistics from the Latin *status.*

The meaning attached to the words *statism* and *statist,* in the writings of poets, essayists, and dramatists, bears out the view just put forward of the proper signification of the term statistics. Milton, for instance, speaks of "statists and lawyers," and elsewhere uses the term in the sense of a man having political power and influence. Ford also uses the word in this latter sense. South speaks of persons who called our religion *statism.*

multitude of causes, has been urged as an objection to the introduction of the numerical method into the service of those sciences. It is admitted, that the use of numbers and averages by the astronomer who deals with the more simple relations of matter, such as magnitude and relative position, and by the engineer who avails himself of its more simple properties, such as its hardness, tenacity and elasticity, have contributed to make the science of the one perfect, and the art of the other safe; but it is contended that the use of numbers cannot be extended beyond such narrow limits with safety or advantage, and that medicine and political economy lie beyond these limits. The actual practice of mankind, founded upon an instinctive perception of the necessity of employing figures in the service of the physician and statesman, may be fairly alleged as a sufficient answer to this objection; but a little consideration will serve to show its futility.

In the first place, it is self-evident that the exclusion of figures from the service of medicine, does not bring about the disuse of those very facts and events which are objected to as unfit to be employed as statistical or numerical elements. The physician will still persist in stating and recording the results of his experience. He will still assert that he has *sometimes* observed this symptom in a certain disease, that he has *often* found that remedy beneficial, that he has *almost never* known such and such a mode of treatment to fail. Those who contend for the use of numbers in medicine, merely insist on the necessity of reducing the *sometimes*, the *often*, and the *almost never* to a more correct and intelligible form of expression; and they argue that it is utterly inconsistent to object to the use of facts as materials or elements of numerical propositions, and yet not to censure the use of these same facts as foundations for loose and inaccurate verbal statements. From this dilemma there is obviously no escape. But, though the objection itself is futile, the misgiving of which it is the exaggerated expression is natural and well founded. It cannot excite surprise that the individual facts or events which own so many concurrent causes should be regarded as requiring, on the part of the observer, a greater degree of care in verifying, recording, collecting, and arranging them than would be necessary in the more simple cases already adduced; and that both the facts themselves, and the numerical expressions in which they are embodied, should be viewed with a proportionate degree of distrust. From this moderate and reasonable view of the case, no advocate of the numerical method will be found to dissent. On the contrary, he will seek to strengthen it by giving due prominence to each separate ground of misgiving, and by laying down stringent rules for the guidance and governance of the observer. Before proceeding to detail some of these rules, it may be well to advert to a probable, and, indeed, obvious cause, of the distrust with which numerical data are sometimes regarded. Indiscreet advocates of the numerical method have sought to apply the general results of collections of cases expressed in the language of figures to the treatment of individual cases of the same disease, without making allowance for those differences between case and case which confessedly existed in the collections themselves. They have used a general principle, as if it had been a rigid and unbending rule of action; forgetting that though, as the experience of assurance offices abundantly testifies, the general results obtained from a large number of individual facts may be safely reapplied to an aggregate of facts of the same nature, they cannot be brought to bear on a single case, or on a small number of cases, without the greatest danger. Each case must be viewed in practice, first as a generality governed by some large law of prognosis, diagnosis, and treatment; and secondly, as a specialty demanding a careful consideration of all its peculiarities.

Among the rules which ought to govern the observer in the collection of facts destined to form the elements of averages, there are some of so simple and obvious a nature as to require no discussion. Such are, the previous preparation of some simple and available form of register, by means of which the several facts may be committed to paper at the very time of observation, so that nothing may be trusted to the memory; the careful selection of the facts themselves; the shaping of the inquiries which may be necessary to elucidate those facts as nearly as may be in the same terms; the avoidance as much as possible of such leading questions as would be likely to bias the respondent, when the facts in question, like most of the particulars which make up the history of diseases, are dependent upon testimony; and especially the purging of the observer's own mind of prejudices and preconceptions in respect of the subject of inquiry.

The careful selection of the facts which are to form the materials of our averages is by far the most important of these rules, and one which demands a little further consideration. If we consider the facts we are observing in the light of phenomena, or events brought about by a multitude of concurrent causes, it will be obvious that care will require to be exercised, not so much in verifying each phenomenon or event as that of which we are in search, as in ascertaining that all the concurrent causes or conditions are, or have been, in operation to bring about that phenomenon or event. The absence of a single cause or condition will vitiate the individual fact, and impair or destroy the value of our average results. A few illustrations will suffice to show what is here intended. We are anxious to determine the true average frequency of the pulse in adult males, in a state of rest, and as free as possible from the influence of all disturbing causes; but, either from ignorance or oversight, we count it indifferently in every position of the body, and at all times of the day. In this case, our facts cease to be comparable facts; for it is well known, that both posture and time of day have a remarkable influence on the number of the pulse. Or, to take another case, we wish to ascertain the influence of some employment upon health (say that of the letter-press printer); but we overlook the important fact, that in every printing office, two or three very distinct occupations are carried on, of which the most important are those of the compositor and pressman. Not being fully aware of this fact, and of the wide difference existing between the two employments, we proceed to extract from some mortuary register the ages at death of printers as a class, calculate the average age at death, and then proceed to group the whole class of printers with that large class of occupations carried on in-doors, with little bodily exertion, to which the compositor alone properly belongs, but from which the pressman is, by the nature of his employment, excluded. In this case, we should have been misled by the common name borne by men following two really distinct occupations, and our facts would again cease to be comparable facts. A third and apt illustration is afforded by the Asiatic cholera. We wish to compare two different remedies or plans of treatment; but we administer the one remedy, or adopt the one plan, at the onset of the epidemic, and the other during its decline. Here, again, our facts are not comparable facts; for it is one of the well-known characteristics of this disease, that it is more severe on its first occurrence than during the period of its decline. The same sort of error would be committed, if one remedy were administered in an early, and the other in an advanced, stage of the attacks themselves. The principle which these illustrations are intended to enforce, is the necessity of selecting, as the elements of the same average, facts strictly comparable, or, in other words, brought about by the same combination of causes. Over the intensity with which each cause acts in individual instances, the observer can exercise no control. His province is to ascertain that the same combination of causes is at work to bring about each phenomenon or event. If from ignorance or oversight he fails in this duty, he impairs the value of his facts, and vitiates his inferences in proportion to the number and force of the conditions that he has overlooked or omitted.

In the observation and collection, therefore, of the individual phenomena or events which are to serve as materials for our average results, the first precaution to be observed is, that those phenomena or events should be strictly comparable as regards the combination of causes by which they are brought about; or, as the French statists express it, we must ensure "*l'invariabilité de l'ensemble des causes possibles.*" The frequent omission of this most necessary precaution has given birth to the dogma of Morgagni — *Non numerandæ sed perpendendæ sunt observationes* — and to the most valid objections urged against the application of the numerical method in medicine. For the collection, arrangement, and classification of the facts which are to form the materials of our averages, no concise rules can be laid down. The tabular forms must adapt themselves to the exigencies of each individual inquiry; and must be more or less complicated as the subjects of investigation consist of few or many particulars. In reporting cases, for instance, and in collecting and analyzing those recorded by others, tabular forms embracing many particulars are required; and the preparation of such forms demands unusual skill and care.* The same remarks apply to the collection and classification of recorded experiences and opinions bearing on particular subjects of inquiry †; a numerical summary of authorities favourable and adverse to particular doctrines, constituting what may be not inaptly termed *the statistics of opinion.*

2. *Of the average and extreme results deduced from observation.* — The observer having exercised all due care in the observation of his facts, having grouped together only those events which owned the same combination of antecedents or causes; and having further correctly performed the work of enumeration, has thus obtained certain average and extreme results, which are to constitute standards of comparison and data for reasoning; the question naturally arises — are these average and extreme results sound and trustworthy standards and data, or not; and what are the circumstances which render them the one or the other? Common sense and experience combine to give an authoritative answer to this question. Our average and extreme results are more or less sound and trustworthy, as the individual facts from which they have been calculated are more or less numerous. Where the facts upon which it is attempted to found a general principle, or to establish a standard of comparison, are very few, we are at once conscious of their insufficiency; and the more readily when an attempt is made to apply the principle or standard in question to some important practical purpose. A better illustration of the futility of such an attempt can scarcely be found than the well-known test of Ploucquet. That author proposed to determine whether or not a child was still-born by referring every doubtful case to a standard of comparison, founded upon three observ-

* On this subject the late Dr. Todd, of Brighton, has written a very able work, which may be safely recommended to all who desire to enter upon such complicated investigations. The title of this work is: — The Book of Analysis, or a New Method of Experience, whereby the Induction of the Novum Organon is made easy of Application to Medicine, Physiology, Meteorology, and Natural History; to Statistics, Political Economy, Metaphysics, and the more complex Departments of Knowledge. By Tweedy John Todd, M.D., of the Royal College of Physicians of London, &c. &c. 1831.

† Reference may here be made to a paper published in the 3rd volume of the Journal of the Statistical Society of London, "On the best Method of Collecting and Arranging Facts, with a proposed New Plan of Common-Place Book." By the Author of this Essay.

ations of the relative weight of the lungs and body; of which three observations, one was made upon the body of an immature infant, so that the subjects of the observations were not strictly comparable. Though Ploucquet, in this procedure, offended against two of the most obvious statistical rules, his test continued to be treated with undeserved respect, till comparatively recent investigations on a larger scale had demonstrated the little reliance to be placed upon it.

The most common attention to the ordinary daily occurrences of life would suffice to caution us against such errors as that into which Ploucquet fell. Coincidences of the most startling character are constantly happening to put us on our guard against them. One which occurred to the writer of this article deserves to be put on record. Two cases of congenital absence of the larger pectoral muscle on the same side of the body, occurred, on the same day, among the out-patients of the King's College Hospital. This defect he has never happened to observe within the wards of that Hospital or elsewhere, either before or since. A similar coincidence, though of a less striking character, presented itself in the same institution while the writer was noticing with some care and interest the complexion and physiognomy of patients suffering from pulmonary consumption. His own previous experience, in conformity with the general opinion, had pointed out the fair complexion as that of the great majority of phthisical patients; but the almost exclusive occurrence for several days together of the olive complexion, among patients labouring under that disease, had almost led him to discard his former opinion and that of the best authorities, and to embrace one which, as farther observation convinced him, would have been erroneous.

Games of chance are constantly furnishing striking examples of these coincidences, in the shape of what is familiarly known as a run of good or ill-luck; the same event, favourable or unfavourable, occurring many times in succession, contrary not only to reasonable expectation, but to the results of unerring calculation. On the other hand, the success of the bank, with only a slight calculated chance in its favour, but with a capital sufficiently large to await the inevitable change in the run of luck, vindicates the sufficiency of large numbers of facts. The great annual fluctuations, too, which take place in the balance of the receipts and expenditure of assurance offices, but the ultimate safety of their transactions, when extending over a long term of years and embracing a large number of insurances, serve to enforce the same truth.

The sufficiency for all practical purposes of large numbers of facts, may also be inferred from the remarkable uniformity observed to take place in the annual summaries of events brought about by the continued operation of the same combination of causes. The annual reports of the Registrar-General supply many illustrations of this principle. The illustration best suited to our present purpose, is one drawn from an event removed, by the very nature of the case, beyond the reach of external influences, or only very remotely and indirectly amenable to them; namely, the proportion of male and female births in successive years. In the eighth annual report of the Registrar-General (p. lxi.), a table is given, in which the number of males and females born, to every hundred living males and females respectively, is recorded for the seven years 1839–45. If we substitute 100,000 for 100, the table will read thus.

Year.	Males.	Females.	Excess of Males.
1839	6,498	6,211	287
1840	6,539	6,250	289
1841	6,580	6,289	291
1842	6,564	6,273	291
1843	6,597	6,305	292
1844	6,676	6,381	295
1845	6,622	6,329	293

The largest excess of male over female births, therefore, in these seven years is 295, and the least 287, the average being 291; so that the extreme fluctuation amounts to only 8 births in about 6500, or considerably less than 1 in 800; while the excess or defect above or below the average of 291 is only 4 births, or less than 1 in 1600. If the causes which determine the births of males and females respectively could be assumed to be constant and uniform, these fractional fluctuations would express the divergences due to the insufficiency of the number of observations to express an absolutely true result. The close approximation actually obtained must be held to prove the sufficiency for every practical purpose of results based upon large numbers of observations.

Having thus shown, by two opposite examples, the total insufficiency of small numbers of facts, and the sufficiency, at least for practical purposes, of large numbers of observations, it will be necessary to enter into a more detailed examination of the relative value of numbers of observations intermediate between these two extremes.

From what has been already stated, it must be obvious that the degree of confidence to be reposed in results based upon different collections of facts must vary with the number of those facts; and that, other things being equal, the value of the results must increase with every addition made to that number. But it is only by actual observation, or by mathematical calculations based upon indisputable data, that the precise value of any particular number of facts can be determined. Observation, indeed, is altogether unequal to give more than a vague and general idea of the relative values of small and large collections of facts; so that we must ultimately resort to the mathematics both for authoritative decisions and safe guides. As, however, the large majority of mankind is destitute of that mathematical knowledge and training which is essential to the appreciation of mathematical rules, it is desirable to show, by an appeal to the results of actual observation, the increasing value of increasing collections of facts, as well as the rate of that increase. For this purpose, it is proposed to make use of some observations collected by the writer of this article. Having had occasion, a few years since, to bring together, from the pages of the Peerage and Baronetage, the ages at death of the male members of the English aristocracy, dying 21 years and upwards, to the number of several hundreds, it appeared to be a favourable opportunity of testing the relative values of large and small numbers of facts, as well as of obtaining a rude approximation to a rule or measure of value. The ages at death, relating, as they do, to members of the same class in society, and taken without selection from the successive obituaries of noble families, constitute a collection of strictly comparable facts, well suited to the purpose in view. The following table, which embodies the results of these facts in their bearing on the question before us, has been formed in the following manner: — The several facts were first arranged in groups of 25 each; two successive groups of 25 were then formed into groups of 50; the groups of 50, in like manner, into groups of 100, and so on, till the last totals in the table were obtained. The greatest and least averages obtained from each group of facts were then selected, and, with the range, or difference between them, thrown into a tabular form.

Number of Facts.	Average Age at Death.		
	Max.	Min.	Range.
25	69·40	50·64	18·76
50	66·44	55·20	11·24
100	63·70	56·85	6·85
200	62·38	57·61	4·77
400	61·10	58·24	2·86
800	60·84	59·67	1·17
1600	60·25		

Now, if we assume the true average duration of life among the members of the Peerage and Baronetage, who have attained their 21st year to extend to 60 years (being the mean of 1600 observations), and, for the sake of simplicity, substitute for the decimals in the table the whole numbers nearest to them in magnitude, it will follow that, in making use of the several groups of observations specified in the first column of the annexed table, we may have the errors in excess or in defect which are enumerated in the second column.

Number of Facts.	Error in Excess or Defect.
25	9½
50	5½
100	3½
200	2½
400	1½
800	0½

These figures, then, represent the extreme error which could have been committed, in this particular case, by relying on 25, 50, 100, 200, 400, and 800 facts respectively. But it must be borne in mind, that this collection of facts is one which, from the very nature of the case, is likely to present a minimum of divergence between the averages deduced from the same number of facts; for the several obituaries, from which the ages at death are taken, register the deaths of one and the same class, inhabitants of the same country, and split into family groups bearing a close resemblance to each other. If, instead of a single class, exposed to similar influences, and not admitting of subdivision into smaller classes, we were to take the members of that large section of the community which is generally known as the upper and middle class, with their numerous subdivisions of employment, and class them by fifties and hundreds, we should encounter a much more considerable divergence. The results of such a comparison for the class in question are embodied in the following table.

Number of Facts.	Average Age at Death.		
	Max.	Min.	Range.
50	84·44	56·78	27·66
100	76·24	58·25	17·99
200	73·54	61·50	12·04
400	69·78	63·51	6·27
800	68·67	65·07	3·60
1600	67·93	64·84	3·09
3200	66·38	65·82	0·56
6400	66·10		

If, as in the former case, we take 66 years to be the true average age attained by the entire middle class, reckoning from 21 years of age, and reduce the range in each case to the nearest whole number, we shall have the following divergences.

Number of Facts.	Error in Excess or Defect.
50	14
100	9
200	6
400	3
800	2
1600	1½
3200	0¼

In this instance, therefore, though we begin with 50 in place of 25 facts, we obtain a possible error in excess or defect of 14 years in place of 9½ years. It must be obvious, then, that the errors to which averages deduced from any given number of facts are liable, will vary with the nature of those facts; and that the extent of possible error will bear a certain proportion to the number of the influences which are brought to bear on each unit of each collection of facts.

It must not, however, be forgotten that the figures in these several tables represent only possible errors. It may happen that the first 25 observations brought together may yield an average differing by less than a single unit from the mean of thousands of observations; and there is always a balance of probability in favour of the average even of a small number of facts approximating more closely to the true average than to the extremes. That this is the case will be evident on the most cursory inspection of the following tables, of which the first is founded upon the facts

Average Age at Death.	25 Facts. 72 Groups.	50 Facts. 36 Groups.	100 Facts. 18 Groups.	200 Facts. 9 Groups.	400 Facts. 4 Groups.	800 Facts. 2 Groups.
69	1					
68	0					
67	0					
66	3	1				
65	4	0				
64	9	2	1			
63	3	3	1			
62	3	5	3	3		
61	9	6	3	0	3	1
60	9	4	3	2	0	1
59	8	5	3	3	0	
58	6	5	1	1	1	
57	5	1	3			
56	6	3				
55	1	1				
54	3					
53	1					
52	0					
51	1					

Average Age at Death.	50 Facts. 128 Groups.	100 Facts. 64 Groups.	200 Facts. 32 Groups.	400 Facts. 16 Groups.	800 Facts. 8 Groups.	1600 Facts. 4 Groups.	3200 Facts. 2 Groups.
84	1						
83	0						
82	0						
81	0						
80	0						
79	0						
78	0						
77	0						
76	1	1					
75	1	0					
74	4	1	1				
73	2	1	0				
72	2	1	0				
71	5	0	0				
70	4	4	0	1			
69	7	3	2	0	1		
68	13	5	3	1	0	1	
67	17	9	4	4	1	0	
66	20	13	14	4	2	1	2
65	5	13	2	4	3	2	
64	16	6	2	2	1		
63	11	1	2				
62	10	4	1				
61	3	1	1				
60	3	0					
59	0	0					
58	0	1					
57	3						

relating to the duration of life of the aristocracy, and the second on the facts relating to the duration of life of the combined upper and middle classes. For the sake of perspicuity, the average of all the facts in either table is distinguished by a larger type.

These tables speak for themselves. In the first table, for instance, the small number of 25 facts is seen to yield the same average as the total of 1800 facts in no less than 9 instances, or one eighth of the whole number; while in 26 out of 72 instances, or more than one third, the average of 25 facts exceeds or falls short of the average of 1800 facts by only a single unit. In like manner, it appears from the second table, that in 20 cases out of 128, or little less than one sixth, the average of 50 facts coincides with that of 6400 facts; and that in 42 out of 128, or nearly one third, it differs from it only by a single unit. Without entering into a minute examination of the other columns of the two tables, it will suffice to state that the probability in favour of an average of a given number of observations coinciding with the true average increases with the number of observations; so that we are again brought back to the expediency of collecting large numbers of observations wherever it is practicable so to do. In using small numbers of facts to establish data for reasoning or standards of comparison, we are bound to speak with diffidence of their sufficiency, and we ought to regard them rather in the light of probabilities requiring to be strengthened by other probabilities, as weak arguments require to be supported by additional reasons, than as, in themselves, worthy of great reliance. According to this view of the case, we are not precluded from the use of averages drawn from small numbers of facts. The employment of such averages with this proviso is an absolute scientific necessity; for in many instances we are prevented by causes too numerous to specify from bringing together facts by the hundred or the thousand, and yet, were we to reject the smaller numbers as inadmissible, we should be thrown back upon the still more loose and less trustworthy general statements from which it is the province of statistics to rescue us.

An examination of the two foregoing tables, as well as of those which display the extreme variations between the averages derived from the same numbers of facts, will serve to prove the hopelessness of any attempt to establish by observation rules for measuring the relative value of averages derived from different numbers of facts. It must be equally evident that no deductions drawn from observation can enable us to state the actual liability to error of any given number of facts, considered as facts, without reference to their peculiar nature. To determine this liability to error belongs solely to the mathematics.

If, on the one hand, observation is unable to supply us with the means of testing the true liability to error of conclusions based on a given number of facts, considered as facts, without reference to their peculiar nature, it must be evident, on the other hand, that mathematical formulæ deduced from abstract reasoning can only supply us with the means of measuring the value of a given number of facts in this their abstract relation, without taking into account the varying quality of the facts themselves. But as it is of the utmost importance to be able to test the abstract sufficiency of a given number of facts to establish a principle or to supply a sound standard of comparison, it will be necessary to enter at some length into this part of our subject.

The facts already adduced, must have abundantly shown that the limits of deviation from a true average result are wider or narrower as the number of facts from which the average is drawn is smaller or greater. Many eminent mathematicians, and M. Poisson among the number, have laboured to convert this general principle into an exact numerical expression or formula, applicable as a test of the true value of larger or smaller collections of facts, and as an exact measure of the limits of variation. M. Gavarret, in his work on Medical Statistics, contends successfully for the introduction of these formulæ into the service of the medical man; and adopting the sentiment of Laplace, "Le système tout entier des connaissances humaines se rattache à la théorie des probabilités," he insists that medical statistics, or, as we prefer to term it, the Numerical Method, applied to medicine, is nothing more nor less than a special application of the Calculus of Probabilities, and the Theory of large Numbers; and that as such it is the most indispensable complement of the experimental method. In other words, he deems it incumbent on the medical man to apply to his numerical results the corrections supplied by the formulæ of the pure mathematics; and before he concludes that any number actually obtained by observation is a true representative of a fact or law, to determine whether that number may not be comprised within the limits of possible variation. M. Gavarret illustrates the necessity of this precaution by applying his mathematical formulæ to a great variety of results based upon observation; but he especially insists upon bringing the alleged efficacy of certain modes of treatment to this searching test. The most convenient course to adopt, in reference to these formulæ, will be to present the calculations based upon them in tabular forms, and then to apply these calculations to one or two striking examples.

The following table presents at one view the possible errors corresponding to average mortalities deduced from different numbers of observations. It is obvious that the table is equally applicable to other contingencies of the same kind, where one of two events is possible in every instance. The mode of using it will be presently explained and illustrated.

Table of the possible Errors corresponding to Average Mortalities deduced from different Numbers of Observations.*

Number of Observations.	Average Mortality by Observation.	Number of Deaths.	Number of Recoveries.	Possible Error.	Number of Observations.	Average Mortality by Observation.	Number of Deaths.	Number of Recoveries.	Possible Error.
25	0·200000	5	20	0·226274	500	0·300000	150	350	0·057965
50	0·100000	5	45	0·120000	500	0·350000	175	325	0·060333
50	0·200000	10	40	0·160000					
50	0·300000	15	35	0·183302	600	0·100000	60	540	0·034641
					600	0·150000	90	510	0·041231
100	0·100000	10	90	0·084852	600	0·200000	120	480	0·046188
100	0·150000	15	85	0·100994	600	0·250000	150	450	0·050000
100	0·200000	20	80	0·113136	600	0·300000	180	420	0·052915
100	0·250000	25	75	0·122474	600	0·350000	210	390	0·055077
100	0·300000	30	70	0·129614					
100	0·350000	35	65	0·134906	700	0·100000	70	630	0·032071
					700	0·150000	105	595	0·038173
200	0·100000	20	180	0·060000	700	0·200000	140	560	0·042762
200	0·150000	30	170	0·071414	700	0·250000	175	525	0·046291
200	0·200000	40	160	0·080000	700	0·300000	210	490	0·048990
200	0·250000	50	150	0·086602	700	0·350000	245	455	0·050990
200	0·300000	60	140	0·091650					
200	0·350000	70	130	0·095392	800	0·100000	80	720	0·030000
					800	0·150000	120	680	0·035707
300	0·100000	30	270	0·048990	800	0·200000	160	640	0·040000
300	0·170000	45	255	0·058309	800	0·250000	200	600	0·043301
300	0·200000	60	240	0·065320	800	0·300000	240	560	0·045826
300	0·250000	75	225	0·070711	800	0·350000	280	520	0·047697
300	0·300000	90	210	0·074833					
300	0·350000	105	195	0·077889	900	0·100000	90	810	0·028284
					900	0·150000	135	765	0·033665
400	0·100000	40	360	0·042426	900	0·200000	180	720	0·037712
400	0·150000	60	340	0·050497	900	0·250000	225	675	0·040825
400	0·200000	80	320	0·056568	900	0·300000	270	630	0·043205
400	0·250000	100	300	0·061237	900	0·350000	315	585	0·044969
400	0·300000	120	280	0·064807					
400	0·350000	140	260	0·067454	1000	0·100000	100	900	0·026833
					1000	0·150000	150	850	0·031937
500	0·100000	50	450	0·037947	1000	0·200000	200	800	0·035777
500	0·150000	75	425	0·045167	1000	0·250000	250	750	0·038730
500	0·200000	100	400	0·050596	1000	0·300000	300	700	0·040988
500	0·250000	125	375	0·054772	1000	0·350000	350	650	0·042661

The use of this table will be best explained by an example. Let us suppose that a medical man, having, for a long time, adopted a particular course of treatment in a certain malady, has arrived at the following results:

120 deaths, 680 recoveries, 800 cases.

The average mortality in this case would be $\frac{120}{800}$, or 0·150000 (see the second column of the table for 800 facts and 120 deaths). At first sight the medical observer would appear to be justified in asserting that under his method of treatment the mortality was at the rate of only 150,000 in 1,000,000 patients, or 15 per cent. But this assertion would be immediately met by the objection that the number of facts is not sufficient to justify this statement, that an average deduced from so small a number as 800 facts can only be received as an approximation to the truth, and that it requires to be corrected by the aid of the figures in the table.

Accordingly, on referring to the column of possible errors corresponding to 800 cases and 120 deaths, we find that the error in excess and defect to which this number of facts is liable, amounts to 0·035707, which error must be added to and taken from the 0·150000, the result of actual observation. It follows, therefore, that the true result must be somewhere between the numbers

0·150000 added to 0·035707, or 0·185707, and 0·150000 dim. by 0·035707, or 0·114293.

* This table is an abbreviation of one given at p. 142. of Gavarret's work, but with additional calculations based on the same formula, for the numbers from 25 to 200 inclusive. The formula from which the figures in the column of possible errors have been calculated is,

$$2\sqrt{\frac{2 \, . \, m \, . \, n}{\mu^3}}$$

in which m represents the number of times that an event A has happened, n the number of times that an event B has happened, and μ the total number of events: so that $m + n = \mu$; $\frac{m}{\mu}$ the average frequency of the events m, as obtained by observation; and

$$\frac{m}{\mu} + 2\sqrt{\frac{2 \, . \, m \, . \, n}{\mu^3}} \text{ and } \frac{\mu}{m} - 2\sqrt{\frac{2 \, . \, m \, . \, n}{\mu^3}}$$

the limits within which the true average, as corrected by the formula, lies.

So that instead of asserting, as we should seem justified in doing, that the mortality under the influence of the treatment adopted amounted to 15 per cent., we could only claim a mortality comprised between the numbers

185,707 and 114,293 in 1,000,000 cases:

or approximatively between the numbers, 19 and 11 per cent.

Uncorrected observation, therefore, would give, as the result of the treatment adopted, 15 per cent., while corrected observation would give some number between 19 and 11 per cent.

The application of the formula given in the note to an actual case will be more instructive than an imaginary example.

M. Louis, in his *Recherches sur la Fièvre Typhoïde*, has attempted to illustrate the treatment of typhus fever, by minutely analysing 140 cases. The result was as follows: —

Number of deaths	(m)	52
Number of recoveries	(n)	88
Total -	(μ)	140.

The mortality in these cases was therefore $\frac{52}{140}$, or 0·37143; and if we were to take this mortality as the strict expression of the results of the treatment adopted, we should shape our proposition as follows: — The mortality of typhus fever, under the treatment adopted by M. Louis, amounted to

37,143 deaths in 100,000 patients;

or, in round numbers,

37 deaths in 100 patients

If, now, we proceed by means of the formula referred to, to determine the possible error attaching to this proposition (*i. e.* to the number of facts upon which it is made to rest), we find it to be equal to

$$2\sqrt{\frac{2 . m . n}{\mu^3}} = 2\sqrt{\frac{2 . 52 . 88}{(140)^3}} = 0·11550.$$

This being the possible error in excess and defect, the true influence of the treatment will be comprised between the following limits: —

$$\frac{m}{\mu} + 2\sqrt{\frac{2.m.n}{\mu^3}} = 0·37143 + 0·11550 = 0·48693$$

and

$$\frac{m}{\mu} - 2\sqrt{\frac{2.m.n}{\mu^3}} = 0·37143 - 0·11550 = 0·25593.$$

Thus all that we really learn from this record of experience is, that, under the treatment adopted, the number of deaths may vary between

48,693 and 25,593 in 100,000 patients,

or approximatively between 49 and 26 in 100 patients.

In other words, if we were to employ the same mode of treatment in a great number of cases of typhus fever, we might lose any number between about a fourth and a half of our patients.*

The same formula is equally applicable to the solution of doubtful questions relative to the results of two or more series of facts which we are desirous of comparing. It may happen that the difference between the average result of one series of facts and that of a second series, is so inconsiderable, as to leave us in doubt whether it may not be explained by a reference to the limits of error to which the number of facts in either return is liable.*

It often happens, that the average results of two series of observations relating to two alternative events (such as the events of death or recovery in particular diseases, the birth of a male or female child, &c.) approximate so closely, that we are at a loss whether to attribute the slight difference existing between the two averages to coincidence, or to the operation of certain efficient causes. If the number of observed facts be small, the difference between the averages derived from the two series of facts may be so slight as to fall short of the difference between the limits of error in excess or defect. The same result may also happen with any number of facts, however considerable. In order to solve the doubts which necessarily attach to such close approximations, a mathematical formula has been brought into requisition, and employed in the formation of tables applicable to this purpose. Such a table is subjoined. The mode of applying it will be presently explained.

The use of this table will be understood from the following example: — In the six years 1839–44 there occurred in England, on the average of those years, 515,478 births, of which 264,245 were males, and 251,233 females. As the difference between these two numbers is not very considerable, a question might arise, whether that difference is not compatible with the error in excess to which half a million of facts is liable. The use of the formula on which the foregoing table is founded, would at once clear up this doubt.

264,245 male births in a total of 515,478, is equal to

512,904 male births in 1,000,000 births.

But, on the supposition that the male and female births are really equal in number, we have the limits of variation equal to 500,000 $+\sqrt{\frac{2}{515478}}$ and 500,000$-\sqrt{\frac{2}{515478}}$, or 500,000+000,624 and 500,000—000,624, or a maximum of 500,624, and a minimum of 499,376. The difference by the formula is, therefore, 1248 in the million, while the observed difference between the highest and lowest number of male births occurring in the six years 1839–44, is 514,809—511,781, or 3,028. The inference, therefore, is irresistible, that the excess of male births is due to some efficient cause or causes, and that it is not merely an error to which the number of half a million of facts is inevitably exposed.†

* Gavarret, Principes Généraux de Statistique Médicale, p. 284.

* For illustrations of this application of the foregoing table, and of the formula from which the figures are calculated, see Gavarret's Statistique Médicale, p. 80. et seq., and notes, p. 274.

† Several applications of this table and of the formula from which the figures are derived, will be

Table of the Limits of Variation compatible with an equal Chance relative to two observed Events.*

Number of Cases.	Limits of Variation.	
100	0·641429	0·358571
150	0·615470	0·384530
200	0·600000	0·400000
250	0·589442	0·410558
300	0·581650	0·418350
350	0·575593	0·424407
400	0·570711	0·429289
450	0·566667	0·433333
500	0·563246	0·436754
550	0·560302	0·439698
600	0·557735	0·442265
650	0·555470	0·444530
700	0·553452	0·446548
750	0·551640	0·448360
800	0·550000	0·450000
850	0·548507	0·451493
900	0·547140	0·452860
950	0·545883	0·454117
1000	0·544721	0·455279
1100	0·542640	0·457360
1200	0·540825	0·459175
1300	0·539223	0·460777
1400	0·537796	0·462204
1500	0·536515	0·463485
1600	0·535355	0·464645
1700	0·534300	0·465700
1800	0·533333	0·466667
1900	0·532444	0·467556
2000	0·531623	0·468377
2500	0·528284	0·471716
3000	0·525820	0·474180
3500	0·523905	0·476095
4000	0·522361	0·477639

Provision having been thus made by the two preceding tables for testing the sufficiency of average results based upon different numbers of facts relating to two alternatives, and determining the possible variation or limits of error to which the numbers of facts in question, considered simply as facts, without regard to their peculiar nature, are liable, provision still remains to be made for testing in like manner the value of those averages, which belong especially to the domains of physiology and hygiene, namely, the average number of the pulse and respiration, the average age at death of different classes of the community, &c. In the absence of tables specially adapted to this purpose, it must suffice to state, in general terms, that the averages derived from a given number of facts are not to be regarded as strict expressions of the truth, but as approximations more or less remote, as the number of facts is less or more considerable.

But a very important question here arises: — To what extent, and under what restrictions, do calculations based on mathematical formulæ and derived from abstract reasoning, admit of application to the results of actual observation? Conceding, as we may safely do, the soundness of the formulæ, there is yet great room to doubt the propriety of their application to the average results of observation. For if we suppose a mathematical formula to be applied successively to a long series of averages derived from the same number of facts, it must obviously administer a similar correction to those averages which happen to coincide with the true average, and to those which lie at the two extremes. This consideration is sufficient in itself to condemn the use of mathematical formulæ, except as a means of exhibiting in a striking light the possible error attaching to a small number of facts, considered abstractedly as facts.

From the foregoing considerations, then, it would seem to follow, that although averages derived from small numbers of facts are subject to a considerable amount of possible error, there is always such a probability of their coinciding with, or not differing widely from, the true averages, as to justify their employment as standards of comparison and data for reasoning. At the same time it must be conceded, that averages derived from small numbers of facts stand in need of a confirmation which averages drawn from larger numbers of facts do not require, and that in using the former we are bound to speak with a reserve proportioned to the scantiness of our materials.

Of extreme values derived from observation. — As averages founded upon large numbers of facts are numerical expressions of true probabilities, so extreme values are expressions, in the same precise language, of possibilities. Both orders of facts have their scientific and practical applications; but those applications which belong to the extreme values have been less attended to than those which pertain to averages.

One obvious use of extreme values is to confirm and strengthen the conclusions drawn from averages. Thus, if we wish to ascertain the relative duration of life of two classes of persons, we may make use of the greatest age attained by either class in confirmation of the mean of all the observations; and the coincidence of the one with the other will give increased confidence in the general result.

Another important use of extreme values is as a test of numerical theories. Two apt illustrations of this application of figures are afforded by that practical science which deals most largely in possibilities — Forensic Medicine. M. Orfila, in his "Traité des Exhumations," states that it is possible to determine

found in the work of Gavarret, so often quoted, from p. 143. onwards, and in the notes at p. 286. et seq.

* The formula employed in the construction of this table is

$$0{\cdot}50 \pm \sqrt{\frac{2}{\mu}}$$

where μ, as before, represents the total of the observed facts. The table will be found at greater length at p. 230 of Gavarret's work on Medical Statistics.

approximatively the stature of the skeleton and of the body by measuring one of the cylindrical bones; but instead of testing the value of this conclusion by making use of the extreme values, he contents himself with a rough average. It appears, however, that if we take several cylindrical bones having the same length, and compare them with the corresponding ascertained stature of the skeleton, the extreme statures are very wide apart. Of seven ulnas, for instance, having each the same length (viz. 10 inches, 8 lines), one corresponded to a stature of 6 feet 1¼ inch, and another to a stature of only 5 feet 5 inches. The difference of 8¼ inches shows the possible error which might be committed by trusting to this standard of comparison, and demonstrates its futility.

The other illustration is afforded by the well-known test of the absolute weight of the fœtal lungs. It used to be laid down as a rough average that in still-born mature children the weight of the lungs was one ounce, and in children that were born alive two ounces. More accurate observation showed that this rough guess was very far from the truth. It was only, however, by the aid of extreme values that the utter worthlessness of this test could be proved. It resulted from the collation of a moderate number of observations that the lowest weight before and after respiration were the same to an unit, while the greatest weight of the lungs of still-born children, in two instances, surpassed the greatest weight of the lungs of children born alive. Nothing could more clearly demonstrate the insufficiency and invalidity of this test.

The same general principle which applies to averages applies also to the extremes, namely, that the value of the extremes increases with the number of observations from which they are selected. It is obvious, however, that a larger number of facts will be required to arrive at a true extreme value than to obtain a close approximation to the true mean: 10,000 facts, for instance, may give a true mean duration of life for the inhabitants of any country; but as many millions may not happen to embrace the greatest attainable age.

The same principles, then, apply both to the mean and to the extreme values derived from observation. To obtain a correct mean or a probable extreme, we must multiply our facts.

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(*William A. Guy.*)

STATISTICS, VITAL. See Vital Statistics.

STOMACH and INTESTINAL CANAL. See Supplement.

SUBCLAVIAN ARTERIES (*Arteriæ subclaviæ*, Lat.; *Artères sous-clavières*, Fr.; *die Schlüsselbein Pulsadern*, Germ.). — These arteries, two in number, are the great vessels destined to supply the upper extremities with blood. Each passes to the corresponding extremity as a continuous trunk, which in its course gives off numerous collateral branches to the larynx, neck, nervous centres, thorax, &c.

The subclavian arteries on the right and left sides respectively differ from each other in their origin, length, direction, and in their relations to surrounding parts,—differences, however, which occur in the first stage of these vessels only: thus, on the right side, the subclavian artery is derived from the Arteria innominata, and on the left from the arch of the aorta; but on both sides alike the lower or outer margin of the first rib marks the termination of each vessel, which, in its further course towards the upper extremity, is designated by the name of Axillary.

The course of each subclavian artery may, in general terms, be described as representing an arch, the convexity of which looks upwards towards the neck, whilst the concavity has an aspect downwards, and corresponds closely to the apex of the lung. On the right side the extremities of this arch are nearly on the same level, the outer, however, passing a little lower down than the inner; whilst on the left side the reverse obtains, the inner (or cardiac) extremity of the arch of the left subclavian artery, which springs from the aorta, being on a much lower level than the outer. Owing to the difference in the origin of these vessels, the left subclavian artery has a stage within the thorax, which does not belong to the artery of the right side.

The subclavian artery on each side is accompanied by a vein of large size; the direction of the vein is much more transverse than that of the artery, so as to resemble in some respect, as Cruveilhier expresses it, "the cord of the arc which the artery describes:" the subclavian vein is consequently the shorter vessel of the two.

The course of each subclavian artery may be divided into *three stages*, to which the majority of anatomists agree in assigning the following limits:—

A *first stage* comprises that portion of the vessel, from its origin, to the inner, or tracheal edge, of the scalenus anticus muscle.

A *second stage* includes so much of the artery as is contained between the scaleni muscles; and the

Third stage extends from the acromial edge of the scalenus anticus muscle to the lower or outer margin of the first rib: at this latter point the axillary artery commences.

According to some anatomists (as Bichat), the outer margin of the scaleni muscles is the limit between the subclavian and axillary vessels; others (as Cruveilhier) insist upon the clavicle as the line of demarcation between these two great trunks; but the stages above assigned to the subclavian arteries are strictly in accordance with the views of British anatomical authorities.

The *subclavian vein* may be divided into *two stages*, which correspond to the second and third stages of the artery; at the inner edge of the scalenus anticus muscle on each side of the neck, the subclavian joins the internal jugular vein to form the vena innominata (of Meckel), *which latter vein consequently corresponds to the first stage of the subclavian artery.*

As the right and left subclavian arteries differ from each other essentially in their first stage, it is necessary to describe them separately in this portion of their course.

First stage of the right subclavian artery. — This portion of the vessel varies from one to two inches in length; it extends from the summit of the arteria innominata to the tracheal edge of the anterior scalenus muscle, and passes in a direction outwards, and slightly upwards. At its commencement it lies to the right of the trachea, and is concealed by the sterno-clavicular articulation.

In this stage the artery is contained *in the antero-inferior triangle* of the neck. The following structures here constitute its *anterior relations*, and are described in the order in which they present themselves in dissection: — The skin, and subcutaneous cellular stratum, with one sheet of the cervical fascia, being divided, the tendon of the sterno-mastoid muscle (sternal origin) is exposed: behind it is a cellular interval of constant existence, though of variable extent, where anastomosing veins and small arterial twigs ramify. The outer edges of the sterno-hyoid and of the sterno-thyroid muscles are more deeply placed; the latter extends much further outwards than the former, and hence it more directly overhangs and conceals the subclavian artery. These muscles are contained in distinct sheaths (furnished by the deep cervical fascia), which isolate them, as well from the superficial as from the deeper-seated parts: the layer of fascia which forms the back of the sheath of the sterno-thyroid muscle is the deepest lamina of the cervical aponeurosis; towards the middle line it invests the front of the trachea, and the deep thyroid veins; externally, it covers the carotid and subclavian arteries, with their accompanying veins, and is connected to the scalenus anticus muscle, whilst, inferiorly, it is attached to the clavicle, to the sternum, and to the "thoracico-cervical septum," through the intervention of which it is connected with the fibrous layer of the pericardium. On the removal of this fascia from the region under consideration, the *immediate anterior relations* of the subclavian artery are exhibited; they are as follow: —

a. The *right vena innominata*, its satellite vein, lies anterior to the artery in the first stage of its course, but on a lower plane, and separated from it by the phrenic and vagus nerves, and by the internal mammary artery.

b. The *internal jugular vein*, which passes downwards and outwards into the subclavian vein, in order to form with it the right vena innominata, crosses the front of the artery nearly at right angles: an interval (the result of the inclination outwards of the internal jugular vein) occurs between this vein and the common carotid artery; and here

c. The *vagus nerve* passes over the subclavian artery; whilst internal to this point the subclavian artery is enveloped in a *nervous sheath*, formed of

d. The *cardiac filaments* of the sympathetic nerve.*

e. Lastly, the *phrenic nerve* constitutes an important anterior relation of the subclavian artery, passing anterior to the very last portion of the first stage of the vessel, though not in contact with it. The trajet of the nerve is external to that of the internal jugular vein, which, as before mentioned, crosses the same aspect of the artery. There is no actual contact between the phrenic nerve and the subclavian artery, because the nerve, as it leaves the inner margin of the scalenus anticus muscle, lies on and crosses the origin of the mammary artery, which thus separates the nerve in question from the trunk of the subclavian. The relation of

f. The *vertebral vein*, to the subclavian artery, is subject to much variety. According to the descriptions of most anatomists, it passes posterior to the artery; but the writer has found this vein nearly as often in front of the artery as behind it; and occasionally he has seen the vertebral vein terminate in two branches, of which one passed on the anterior, and the other on the posterior aspect of the subclavian artery, so as to encircle that vessel before they opened into the vena innominata. When the vertebral vein is single, and passes over the front of the subclavian artery, it usually lies internal and parallel to the internal jugular vein.

The *anterior relations of the first stage of the right subclavian artery*, are, therefore, the following: —

1. Integument, subcutaneous areolar tissue, fascia.
2. Sterno-mastoid muscle, sterno-clavicular articulation.
3. Sterno-hyoid and thyroid muscles, isolated from one another, and from the last-named muscle, by layers of the cervical fascia.
4. The deep layer of the cervical aponeurosis.
5. The phrenic and vagus nerves, and the cardiac filaments of the sympathetic nerve.
6. The right innominate, and internal jugular veins, and *sometimes*
7. The vertebral vein.

The remaining relations of the artery in its *first stage* are the following: —

Inferiorly, it corresponds to the loop of the

* Vide art. NECK, vol. iii. note to p. 575.

recurrent nerve, *which sometimes has an anterior relation to the artery also,* in consequence of its arising from the pneumogastric at an unusual height in the neck.

Superiorly, it gives off the vertebral artery opposite a triangular interval, between the scalenus anticus and longus colli muscles.

Posteriorly, it corresponds from within outwards, to the transverse process of the seventh cervical vertebra, to the inferior cardiac filaments and inferior cervical ganglion, of the sympathetic nerve, to the recurrent nerve, and finally, to the cone of the pleura.

Nearly *the outer half* of the posterior surface of this portion of the subclavian artery is thus closely related to this serous sac, being usually that part of the vessel which is external to the origin of the vertebral branch, and covered on its anterior surface by the internal jugular vein.

First stage of the left subclavian artery.— The subclavian artery on the left side arises within the thorax, from the termination of the second stage of the arch of the aorta, at the level of the second dorsal vertebra; it thence assumes a direction nearly vertically upwards, to the inner margin of the scalenus anticus muscle, and lies to the left side of, and anterior to, the two upper dorsal vertebræ, from which it is but a short way distant.

Whilst in the cavity of the thorax, the left subclavian artery corresponds, *posteriorly*, to the inferior cervical ganglion, and cord of the sympathetic nerve, to the thoracic duct, and more remotely to the longus colli muscle and spinal column. *Anteriorly*, it is in relation with the pleura, and more immediately with the left pneumogastric and phrenic nerves (the latter descends parallel to the artery, but the former crosses it very obliquely, from above downwards and inwards), with the vertebral vein, the confluence of the internal jugular and left subclavian veins, and the great venous trunk which they form by their confluence, viz. the left vena innominata. *Internal and posterior* to the artery are placed the œsophagus and the left recurrent nerve; *internal and anterior* to it, is the left common carotid artery; whilst *external* to the artery, throughout the entire of its thoracic stage, are the left lung and pleura.

After a course within the thorax of about two inches and a half, the left subclavian artery pierces the "thoracico-cervical septum," inclines outwards and a little forwards, and attains the tracheal edge of the scalenus anticus muscle, when it bends abruptly outwards; this *terminating portion* of the first stage of the vessel (which alone belongs to the cervical region) has, *anterior* to it, the left internal jugular vein, the vagus and phrenic nerves, and the thoracic duct, just before its termination in the great subclavian vein; in addition to these relations, the left subclavian has *the same coverings* as the corresponding portion of the subclavian artery on the right side.

Differences between the right and the left subclavian arteries, in their first stage.—Length. The first stage of the left subclavian artery is much longer than that of the right, which it exceeds by about the length of the Arteria innominata. In the old subject, however, the difference is scarcely so great, for at this period of life, the part of the arch of the aorta, from which the left subclavian artery arises, is higher than that portion of it from which the innominata springs.

Position.—The left subclavian artery is nearer to the spinal column, the right to the clavicle and sternum; consequently the *depth* of the artery from the surface is considerably greater on the left side than on the right, a circumstance which adds greatly to the difficulty of the operation for securing the left subclavian artery in a ligature.

Direction.—On the left side, the artery in its first stage runs almost vertically, but as it approaches the scaleni, it inclines outwards and forwards, in order to pass between these muscles; this latter part of the vessel is situated in the neck, and is the only portion of its first stage found there. On the right side, the subclavian artery runs nearly horizontally outwards, and is placed throughout the whole of its first stage within the limits of the antero-inferior triangle of the neck; for although somewhat concealed at its origin by the sterno-clavicular articulation, yet it may be removed from under cover of that joint, by extending the neck, and depressing forcibly the shoulder and clavicle.

Relations.—a. *Pleura.*—The pleura is an anterior relation of the commencement of the left, but a posterior relation of the termination of the right subclavian artery.

b. *Veins.* —1. *The satellite vein* of the right subclavian artery, in its first stage (the right *vena innominata*), is parallel to the artery, though on a plane anterior and inferior to it, whilst the corresponding vein on the left side crosses the left subclavian at right angles.

2. *The internal jugular vein* runs parallel to the left, but intersects at right angles the front of the right subclavian artery.

3. *The vertebral vein* is usually anterior to the artery of the left, but posterior to the artery of the right side.

c. *Nerves.*—The *phrenic*, *vagi*, and *sympathetic* nerves are necessarily parallel to the left subclavian artery, in the first stage of its course, in consequence of its vertical direction, whilst they run at right angles to the corresponding part of the right, by reason of its transverse course; in other respects, however, these nerves hold the same relative position to the subclavian arteries at either side, the phrenic and vagus being anterior, and the sympathetic posterior, to the right and left subclavians respectively. Lastly, the *recurrent laryngeal* nerve passes behind the right subclavian artery, looping round its under surface, whilst the nerve on the left side encircles the arch of the aorta, internal to the origin of the left subclavian artery; the recurrent is consequently related to the inner side of the left subclavian artery, but at no part of its course does it lie posterior to that vessel.

d. *The thoracic duct and œsophagus* are connected with the artery of the left side, exclusively. *The former* holds a double relation to that vessel; *in the thorax* it passes *behind it*, *in the neck* it rises high above it, and then bends downwards *in front of it*, to open into the confluence of the great veins. *The œsophagus*, as has been mentioned, lies to the right of the artery.

The differences which have thus been pointed out, are of material importance with reference to the operations upon these two arteries.

In the remainder of their course the subclavian arteries are perfectly symmetrical, and one and the same description will apply to both.

Subclavian arteries in their second stage. — In its second stage each subclavian artery lies in a remarkable intermuscular space, bounded by the scaleni muscles. These muscles (scalenus anticus and scalenus posticus) are closely approximated to each other at their attachment to the tubercles of the cervical transverse processes; but in descending to their insertions they diverge, leaving between them a space truly triangular, of which the base, placed inferiorly, corresponds to the first rib, and to a small portion of the second. In this space the subclavian artery, the brachial plexus of nerves, and the cone of the pleura, are situated. *In front*, the artery is in contact with the *anterior wall* of this triangle, constituted by the *scalenus anticus* muscle; *behind*, it is separated from the posterior boundary of the triangle by the summit of the *cone of the pleura*, which ascends thus high into the interval between the scaleni, interposing itself between the scalenus posticus and the subclavian artery. Towards the summit of this "*scalene triangle*" the nervous cords which constitute the brachial plexus are placed along the convexity of the artery, superior and external to it.

A fleshy slip (*Scalenus minimus*, Sœmmering) is often found to pass from the scalenus anticus to the lower, or costal extremity, of the scalenus posticus; in this course it runs *between the roots* of the brachial plexus, and consequently subdivides into two the scalene space. The *lower compartment* contains the subclavian artery, the cone of the pleura, and the inferior portion of the brachial plexus, constituted by the seventh cervical nerve, and the cord resulting from the union of the eighth cervical, with the first dorsal nerve; whilst in the *upper compartment* (corresponding to the apex of the triangle), the fifth and sixth nerves of the plexus are seen to unite into a single trunk.

On the front of the scalenus anticus, and separated by that muscle from the subclavian artery, are found the following parts: — Most inferiorly the subclavian vein, lying on the tendinous insertion of the muscle, and under cover of the clavicle; above the vein the transverse branches of the thyroid axis, viz. the supra-scapular, and the transversalis colli arteries, of which the former is the more inferior, whilst the phrenic nerve descends obliquely inwards towards the tracheal edge of the muscle, and intersects these two transverse arteries by passing behind them.

Superficial to all these important structures is the clavicular origin of the sterno-cleido-mastoid muscle. In size, shape, and direction, this muscle accurately corresponds to the scalenus anticus, which lies deeper than it, and from which it is separated by the parts just now stated, to lie on the front of that muscle.

The separation of the subclavian vein from the subclavian artery in their second stage, "constitutes one of the most remarkable features in its (anatomical) history;" this condition is not, however, constant, for the vein has been found to lie with the artery between the scaleni (Blandin), and, in a few other equally rare instances, the artery has accompanied the vein superficial to both muscles (Manec, Quain). Lastly, the artery has been seen to pass through the anterior scalenus, and hence to lie in part behind and in part in front of that muscle (Quain). It is to be understood that these deviations from the normal arrangement are remarkably infrequent.

The *anterior relations of the subclavian artery in its second stage*, may be arranged in *four orders of parts*: —

1. Skin, platysma, fascia.
2. Sterno-cleido-mastoid muscle (its clavicular origin).
3. Subclavian vein, supra-scapular and transverse cervical arteries, phrenic nerve.
4. Scalenus anticus muscle.

Subclavian artery in its third stage. — After the subclavian artery emerges from beneath the scalenus anticus muscle, it inclines downwards and outwards, and thus completes the arch which its entire course represents. In this stage its position is marked by precise limits, which are always recognisable, even in the living subject. The artery, with the vein and brachial plexus of nerves, which still accompany it, is here contained in the postero-inferior triangle of the neck (*Omo-clavicular space*, Velpeau), the several boundaries of which are constituted by the clavicle, and by the sterno-mastoid and omo-hyoid muscles.

Whilst traversing this region the subclavian artery *lies* at first *on* the scalenus posticus, and then passes on the upper surface of the first rib. *The subclavian vein* lies inferior and internal to the artery, and on a more superficial plane than it, throughout the entire of this portion of its course; it also passes with the artery over the first rib. Two superficial grooves in the adult bone mark the trajet and relative position of these great vessels; a *tubercle*, which gives insertion to the scalenus anticus muscle, separates these grooves from each other (that for the artery is the more posterior of the two); it is constantly present, and serves as a guide to point out with precision the situation of the artery, and so assist the operator to distinguish that vessel from the parts which surround it. Such a guide to the artery is peculiarly valuable, because, in operations upon the larger blood-vessels, the touch often fails to discriminate the proper object, the characteristic pulsation of a large artery being, under such circumstances, often wanting.

In the postero-inferior triangle of the neck the artery is *covered by* the integument, superficial fascia and platysma, descending superficial (*supra-clavicular*) twigs of the cervical plexus, and by the external jugular vein. The situation of this vein in the supra-clavicular space, is subject to much variety; it most frequently runs near to the inner boundary of the triangle and parallel to the outer edge of the sterno-mastoid muscle, but frequently descends in the very centre of the space; in the latter case it much embarrasses the operator in attempting to expose the subclavian artery.

Next in order, a number of conglobate glands, and a plexus of anastomosing veins, principally from the scapular region, come into view; these latter usually communicate with the external jugular, or with the subclavian vein. Areolar tissue which presents a laminated arrangement encloses these glands and superficial vessels, and isolates them from the deeper-seated parts.

These structures being removed, the subclavian artery appears to lie within a *second triangle* of smaller dimensions, bounded *internally* by the scalenus anticus muscle, *externally and superiorly* by the omo-hyoid muscle, and *inferiorly* by the first rib; this bone represents the base of the triangle, and over it the artery is seen to pass. At this depth, two collateral arterial branches of considerable size cross the supra-clavicular space, the one, the transversalis colli, *above*, the other, the suprascapular, *below* the level of this portion of the subclavian artery; the latter is placed under cover of the clavicle, and in contact with the front of the subclavian vein. As the suprascapular artery pursues its course towards the shoulder, it crosses in front of the subclavian artery and of the brachial plexus of nerves. Here likewise the clavicle and the subclavius muscle constitute additional anterior relations of the subclavian artery, now near its termination.

The nervous bundle of the brachial plexus is parallel to the subclavian artery in its third stage, and lies superior and external to the vessel; in its descent the lower division of the plexus overhangs the artery, and one or two of the branches (*anterior thoracic*) cross the anterior surface of the artery, and sometimes even encircle it in a nervous loop.

The *anterior relations of the third stage of the subclavian artery* may therefore be thus arranged:—

1. Integument, superficial cutaneous nerves, platysma, fascia.
2. Areolar tissue in layers, glands, external jugular vein, an intricate plexus of smaller veins.
3. Anterior thoracic branches of the brachial plexus, the subclavian vein, supra-scapular artery, clavicle, and subclavius muscle.

Anomalies in the origin of the subclavian arteries.—1. *The right subclavian artery* sometimes arises separately from the arch of the aorta, in which case there is no arteria innominata; the branches that arise from the arch of the aorta are then four in number, but considerable variety has been observed in the relation which the right subclavian bears to the other three branches; thus,

a. It may occupy the usual position of the innominate artery, being *the first* in order of the branches of the arch of the aorta; its relations within the thorax will then correspond with those assigned to the vessel whose place it comes to occupy.

b. It may be *the second* in numerical order of the branches of the arch, arising after the right carotid artery, behind which it subsequently passes to arrive at its proper position in the neck.

c. It may arise after the two carotids as *the third* branch of the arch; or,

d. It may be *the last* branch of the aorta, and occupy the usual situation of the left subclavian artery. Of the varieties already mentioned, this is the most frequently met with, and, according to the statistics of Professor Quain, it occurs once in every 250 examinations.

e. Sometimes (but much more rarely) this vessel arises *below the arch*, from the thoracic aorta, and its position may be so low, that it will furnish some of the upper intercostal arteries.

The course of the artery, when it thus arises from the left of the arch, is very remarkable; it crosses in front of the spinal column, either behind the œsophagus, or between that tube and the trachea, and necessarily passes across the neck behind all the other branches given off from the arch of the aorta. When thus abnormally situated behind the œsophagus, it has been accidentally wounded by a foreign body which had first transfixed that tube. A remarkable example of this occurrence is mentioned by Mr. Kirby, in the 2d vol. of the Dublin Hospital Reports.

The irregularity in question, of the right subclavian artery, was regarded by Dr. Bayford as the cause of difficult deglutition, in a case which had been accurately observed for many years, and this new disease, as he considered it, he quaintly termed "*Dysphagia lusoria.*" *

In those instances, where the right subclavian artery has been found to deviate thus strangely from its usual course, the inferior laryngeal nerve presented a remarkable change of direction, depending no doubt on the altered course of the artery; in all the instances which were noted, the nerve was given off from the pneumogastric, higher up than usual, and passed directly to the larynx, so as not to be entitled to the name of "recurrent." Dr. Hart, who first directed attention to this fact, has thus clearly explained the connection between the unusual position of the artery and

* Memoirs of the Medical Society of London, vol. ii. 1793.

the altered direction of the nerve: "In the earlier periods of the existence of the fœtus, the rudiment of the head appears as a small projection from the upper and anterior part of the trunk, the neck not being yet developed. The larynx at this time is placed behind the ascending portion of the arch of the aorta; while the brain, as it then exists, is situated so low, as to rest on the thymus gland and front of that vessel. Hence it is that the inferior laryngeal nerves pass back to the larynx, separated by the ascending aorta, the left going through its arch, while the right goes below the arteria innominata.

" As gestation advances, the head becomes more distinct, and the neck begins to be formed after the second month, which, as it lengthens, has the effect of removing the brain upwards to a greater distance, and of drawing out the larynx from the chest, in consequence of which the nerves of the par vagum and their recurrents become elongated, and hence the circuitous route the latter are found to take afterwards, forming loops in which the aorta and right subclavian artery are, as it were, suspended."*

2. *The left subclavian artery* is much less liable to vary in the mode of its origin than the right; the varieties observed are also fewer in number. *a.* The origin of the left subclavian artery is sometimes more approximated than usual to the origin of the left carotid, and in a few instances, *b.* its origin is fused into that of the latter, so that these two vessels arise by a common trunk, which is a *left arteria innominata.*

It has been observed in those instances where the arch of the aorta is reversed, so as to pass from left to right, that the same irregularities affect the transposed branches which then arise from it, as have been stated to occur when the arch holds its more usual position.

Branches of the subclavian arteries.—In the number and arrangement of the branches of the subclavian artery so much variety occurs, that no general description could, perhaps, be given, which would accurately describe their arrangement in any one instance, and hence, in works on anatomy, much discrepancy exists on this subject; the following description agrees with that of the best authorities in this country, and is strictly in accordance with the accurate statistical details of Professor Quain.

In its *first stage* the subclavian artery usually gives origin to the following branches—the *vertebral, internal mammary*, and *thyroid axis;* the last, after a very short course, divides in a radiating manner into the *inferior thyroid*, the *supra-scapular* (transversalis humeri), and the *transverse cervical* (transversalis colli) arteries; besides, in the majority of instances, the *left subclavian artery*, in its first stage, furnishes (in addition to the branches already enumerated) the *superior intercostal artery*, a branch which, on the right side, more frequently arises under cover of the scalenus anticus muscle. All these branches arise nearer to the scaleni muscles, and are consequently more immediately covered by the internal jugular vein on the left side of the neck than on the right.

The position of these branches of the subclavian artery, especially on the right side, is of much interest in a surgical point of view. " The situation in which the branches arise *from any large artery* is an important consideration in its history, because of the influence which their presence has on the result of an operation for the cure of aneurism. And, considering the shortness of the trunk, the size of the offsets, and the manner of their arrangement on the parent vessel, it may be confidently stated that there is no artery in which the influence alluded to is more considerable than in the subclavian."*

The following statistics, derived from the author just quoted, are useful to show the average length of the subclavian artery, from its origin to the point where its first branch arises; in other words, the extent of the artery in its first stage, suitable for the application of a ligature.

In sixty-five bodies examined, this distance measured—

$\frac{1}{2}$ inch and under - - -	in 8
More than $\frac{1}{2}$ inch and not exceeding 1 inch - - - -	„ 33
More than 1 inch and not exceeding $1\frac{1}{2}$ inch - - - -	„ 23
$1\frac{3}{4}$ inch (the extreme length) -	„ 1

Occasionally, the vertebral, or inferior thyroid artery, has been seen to arise *very close* to the arteria innominata.

In the *second stage* the subclavian artery most frequently gives off but a single branch, which soon subdivides into the *cervicalis profunda* and *superior intercostal* arteries. It is less usual for these two arteries to arise *separately;* thus, in 285 examinations, this occurred in the proportion of but 1 to $20\frac{1}{2}$, whereas the former arrangement existed in 266 out of the entire number.

In the majority of instances no branches arise from the subclavian artery *external to the scaleni;* but the *posterior scapular artery* (in general the continued trunk of the transversalis colli) frequently arises from the third stage of the subclavian, and so frequently, indeed, that Cruveilhier regards it, not as a variety, but as the normal arrangement. It is computed by Professor Quain that this occurs in the proportion of 1 in $2\frac{1}{6}$ cases.

I. *Vertebral artery.*—This artery, which is the first and largest, is at the same time one of the most regular of the branches of the subclavian artery, from the upper and posterior

* Dr. Hart, in Edinb. Med. and Surg. Journal, 1826.

* Anatomy of the Arteries of the Human Body, with its Applications to Pathology and Operative Surgery (Plates). By Prof. Quain. Part VI.

aspect of which it usually arises. There is no example on record where this branch arose either between or beneath the scaleni muscles.

From its origin, the vertebral artery assumes a direction upwards, backwards, and slightly outwards to the foramen, in the transverse process of the sixth cervical vertebra; having passed through this, it is transmitted from vertebra to vertebra by the foramina which their transverse processes present, until finally it traverses the foramen magnum, where its cerebral, or cranial, stage commences.

Relations.—From its origin until it enters the transverse process of the sixth cervical vertebra, the vertebral artery is placed in a muscular interspace, between the longus colli and the scalenus anticus muscles, where it is related *in front* to the trunk of the subclavian artery, to its own vein, and to the inferior thyroid artery; the last of these, as it passes transversely inwards, is interposed between the *vertebral vessels* and the *sheath of the carotid artery* (in the sheath, the internal jugular vein exactly corresponds to the anterior surface of the vertebral artery). By its *posterior surface*, the vertebral artery is in relation with the inferior cervical ganglion of the sympathetic nerve.

From the sixth to the second cervical vertebra inclusive, the vertebral artery is lodged in the bony foramina of the transverse processes; in the spaces *between* these, it is enclosed by the pairs of *intertransverse muscles*, being in close contact with the anterior set, whilst from the posterior it is separated regularly by the spinal nerves in their trajet outwards. In this part of its course the artery is slightly tortuous, a provision, no doubt, to guard it against injury in the free and varied motions of this portion of the spine. For a similar reason its tortuosity *increases* remarkably in the subsequent stage.

Having passed through the transverse process of the axis, the vertebral artery inclines outwards and slightly upwards, to reach the foramen in the transverse process of the atlas, a deviation from the former vertical course of the artery which is rendered necessary by the superior breadth of the first vertebra.

Whilst engaged in the curved canal (*not* foramen) of the transverse process of the atlas, the artery bends abruptly backwards and inwards, so that on emerging from this bone it becomes *horizontally* placed on the upper surface of the posterior arch of the atlas. Between the occipital bone and the atlas the artery describes *a curve*, of which the concavity, looking forwards and inwards, embraces the occipito-atlantal articulation, whilst the convexity, directed backwards and outwards, is contained in a *triangular space*, circumscribed in the following manner by the small rotator muscles of the head. The *sides* of this triangle are constituted by the superior and inferior oblique muscles respectively, the *apex* is at the transverse process of the atlas, where both these muscles are attached; whilst the rectus capitis posticus major (placed internally) represents the *base*. Deeply situated in this triangular space, the vertebral artery is *covered* by the splenius and complexus muscles, and rests on the posterior arch of the atlas; the bone presents a groove for the reception of the artery; but the sub-occipital nerve, which frequently forms its ganglion in this situation, is interposed. The space which has just been described is occupied by yellow, granular-looking fatty matter, and the occipital artery winds along its upper boundary, freely anastomosing with the vertebral.

The vertebral artery next passes beneath the lower edge of the posterior occipito-atlantal ligament, then perforates the dura mater, and, taking a direction upwards, forwards, and inwards, enters the cranium through the foramen magnum. The posterior occipito-atlantal ligament, by arching over the groove on the upper surface of the atlas, forms a foramen for the transmission of the artery.

As the vertebral artery advances through the foramen magnum, it passes *between* the first and second tooth-like insertions of the ligamentum dentatum, and then ascends, lying *on the anterior surface* of the first of these processes, by which it is separated from the *spinal accessory nerve*, which latter passes upwards *on the posterior surface* of the ligament; here the *lingual nerve* passes outwards to the anterior condyloid foramen, *above* the level of the artery.

Within the cranium, the vertebral arteries, corresponding at first to the lateral aspects of the upper portion of the medulla oblongata, approximate to each other more and more as they ascend, and ultimately unite at an acute angle, opposite the inferior edge of the pons varolii; in this manner the *basilar trunk* is formed.

Basilar artery (*Artère méso-céphalique*, Chaussier).—This artery, larger than either of the vertebral arteries, is yet much less capacious than the two vessels conjointly which unite to form it; its length corresponds accurately to the longitudinal measurement of the pons varolii; it runs along the median depression of the pons, lodged between that body and the upper surface of the basilar process of the occipital bone, and preserved from pressure by the double concavity of the surfaces between which it is interposed.

At its commencement the basilar artery separates from each other the sixth nerves of the opposite sides; the arachnoid membrane and the dura mater, with the transverse sinus of Haller, are interposed between the artery and the bone, whilst the pia mater alone intervenes between it and the pons. At the antero-superior edge of the pons the basilar artery usually terminates in four branches, two for the cerebrum and two for the cerebellum.

Branches of the vertebral artery. — 1. Branches to the prævertebral muscles, which anastomose with the cervicalis ascendens and superficialis colli arteries.

2. Numerous small branches, which enter the spinal canal through the intervertebral

foramina, and which are conducted by the nerves to the spinal cord, where they join and reinforce the proper spinal arteries.

3. In the space between the atlas and occipital bone, the vertebral artery sends several long branches down the neck, which are concealed by the splenius and complexus muscles. Accompanied by smaller branches of the occipital, these arteries keep up an important anastomosis on the back of the neck with the cervicalis profunda.

4, 5. The proper *spinal arteries.* These are two in number on each side, an *anterior* and a *posterior* branch from each vertebral trunk.

The *posterior spinal arteries* arise lower down than the anterior, and pass downwards and backwards to reach the posterior surface of the medulla oblongata; from this the artery of each side descends parallel to its fellow, to which it is connected by numerous transverse branches. Opposite the second lumbar vertebra, the posterior spinal arteries cease to exist as distinct trunks.

The *anterior spinal arteries* are given off from the vertebral near to its termination; these arteries in descending approximate to each other, and at last unite opposite the lower edge of the medulla oblongata; the single trunk thus formed (*anterior median artery of the spinal cord*) descends tortuously in front of the medulla spinalis, and, passing through the very centre of the fibres of the cauda equina, reaches the lowest portion of the vertebral canal, when it anastomoses with branches of the sacral arteries.

The anterior and posterior spinal arteries are connected in every region of the spine with branches of arteries which enter the spinal canal through the "foramina of conjunction;" these *reinforcing branches*, as they may be termed, of the spinal arteries (derived from the cervicalis ascendens and vertebral in the neck, from the intercostal in the back, and from the lumbar and sacral arteries in the lower portion of the spinal column), cause these arteries which they join to preserve a remarkable uniformity of size throughout their entire course. Both the spinal arteries furnish small branches to the dura mater and to the spinal cord.

Branches of the basilar artery. — 1. *The inferior (or posterior) cerebellar artery.* — This artery seldom arises in precisely the same manner at opposite sides of the same subject. It most frequently springs on one side from the vertebral, and on the other from the basilar trunk. Inclining outwards and backwards, in front of the pyramidal body, the vessel in question passes (according as its origin is from the basilar, or from the vertebral artery) *before or behind* the sixth nerve; it then runs through the filaments going to form the ninth nerve, and between the pneumogastric and spinal accessory division of the eighth pair; it is ultimately distributed *internally* to the inferior vermiform process and sides of the median fissure (a branch or two may be traced into the choroid plexus of the fourth ventricle), and *externally* to the inferior surface and circumference of the cerebellum, where it communicates with the superior artery of the cerebellum.

2. *The superior (or anterior) cerebellar artery.*—This artery arises near the antero-superior edge of the pons varolii; it passes in a curved direction outwards and backwards, around the line of junction of the pons with the crus cerebri. It is at first parallel to the posterior artery of the cerebrum, but separated from it by the third nerve. The fourth nerve in its trajet forwards is strictly parallel to the artery as it runs backwards on the side of the pons varolii; the nerve, however, is contained in a canal between the layers of the tentorium, whilst the artery proceeds beneath that partition, and in contact with the upper surface of the cerebellum.

The *branches* of the superior cerebellar artery are numerous; they are distributed to the upper surface and circumference of the cerebellum, anastomosing with the inferior cerebellar artery, and also to the pons varolii, velum interpositum, superior vermiform process, and valve of Vieussens. One small branch of this artery accompanies and separates the facial and auditory nerves, entering with them into the internal auditory meatus. Lastly, some of its branches pass on the upper surface of the tentorium, and are distributed to the inferior surface of the cerebrum.

3. *Posterior artery of the cerebrum.* — The two posterior arteries of the cerebrum are the terminating branches of the basilar trunk; each artery passes at first forwards, then backwards and outwards, following the course of the great cerebral fissure, and partly encircling the crus cerebri. For a considerable portion of its course the posterior artery of the cerebrum is parallel to the posterior (or inferior) cerebellar artery; the two arteries, however, are separated from one another, at first, by the third nerve (which latter, in its further course, hooks round the posterior artery of the cerebrum), and subsequently by the tentorium. At the point where the posterior artery of the cerebrum changes its direction in order to pass backwards and outwards, it is joined by the "posterior communicating artery," and by this means a communication is established between the internal carotid and basilar arteries.

The posterior artery of the cerebrum is chiefly distributed by long slender branches to the inferior surface of the posterior lobe of the cerebrum, but it furnishes, in addition, the following collateral branches:—1. Numerous small twigs which enter the floor of the third ventricle, through the apertures in the locus perforatus medius, or are distributed to the crura cerebri, corpora albicantia, and tuber cenereum; and 2. a *choroid branch*, which winds round the crus cerebri, enters the cerebral fissure, and is lost in the velum interpositum, corpora quadrigemina, and choroid plexuses.

Varieties occasionally observable in the vertebral arteries. — 1. *Of origin.*—*a.* It has already been mentioned that the vertebral artery may arise from different portions of the first stage of the subclavian artery being sometimes nearer, and sometimes further removed, from the innominata; but, independently of these varieties, the vertebral artery *on the right side* is

b. Sometimes furnished by the common carotid artery. In all the cases where this anomaly has been observed, the right subclavian artery was given off *directly* as a branch of the aorta. Again,

c. The vertebral artery sometimes comes off from the arch of the aorta. This irregularity is as unfrequent on the right, as it is common on the left side. When the *left* vertebral artery springs from the arch of the aorta, it usually arises *between* the left carotid and the left subclavian arteries, though sometimes its origin has been found to the left of all the other branches of the arch.

d. In a few instances, more than one vessel has been found to constitute the origin of the vertebral artery; thus, it may be formed by the union of *two roots*, both arising from the subclavian artery, or one from the subclavian and the other from the aorta. In one example, where it was formed by *three roots*, two of these were derived from the subclavian, and the third from the inferior thyroid artery. These roots of the vertebral artery in some instances united before the artery had become engaged in the vertebral foramina, whilst in others the union took place subsequently.

2. *Of size.*—There is often a considerable difference in the size of the two vertebral arteries, which is stated to be most frequently in favour of that of the left side; thus, in 98 observations made by Mr. Davy, the *left* vertebral artery was the larger in *twenty-six*, and the *right* in *eight* instances only.

3. *Of course and relations.*—The vertebral artery may enter the transverse process of the last cervical vertebra (though the contrary has been asserted), or it may enter one of the foramina higher than that in the transverse process of the sixth, which latter it usually selects. When the artery enters any vertebra higher than the sixth cervical, it always occupies an unusually superficial position in the neck, lying external and parallel to the common carotid artery, for which, consequently, it is liable to be mistaken. (*Vide* CAROTID ARTERY.)

The *vertebral vein* corresponds to the cervical stage only of the artery. Its origin is found in some branches from the deep muscles at the back of the neck, joined by one from the occipital vein, and by another which passes through the posterior condyloid foramen. The vertebral vein traverses the canal in the transverse process of the atlas, and descends through the same foramina by which the artery ascends; whilst here it lies *in front* of the artery, and has the same relations as that vessel. Emerging from the foramen in the sixth vertebra, the vertebral vein (liable to the varieties already specified) opens into the vena innominata close to its junction with the internal jugular.

II. *Internal mammary artery.*—This artery arises (more externally than the vertebral) from the anterior surface of the subclavian, and near to the inner margin of the anterior scalenus muscle. From this origin it runs, first forwards, then downwards and inwards, and enters the thorax, lying between the pleura and the internal layer of intercostal muscles.

Previous to entering the thorax, the internal mammary artery is crossed anteriorly by the vena innominata and by the phrenic nerve: the latter intersects the artery obliquely from above and without, downwards and inwards. In the thorax, however, the nerve attains a position much posterior to the artery.

The mammary artery descends on the back of the anterior parieties of the chest a little external to the junction of the costal cartilages with the sternum, and is covered posteriorly by the pleura at the line of reflexion of that membrane to form the side of the anterior mediastinum. Arrived at the cartilage of the third rib, the artery in its farther descent inclines a little outwards, and becomes separated from the pleura by the fibres of the triangularis sterni; the vessel is now placed between that muscle, which lies behind it, and the internal layer of intercostal muscles and the cartilages of the lower true ribs, which constitute its anterior relations. Opposite the cartilage of the seventh rib the mammary artery terminates by dividing into two branches, an *external* and an *internal*.

Branches of the mammary artery. — 1. *Mediastinal branches*, which are distributed to the thymus gland (*thymic arteries*), and the cellular issue of the anterior mediastinum.

2. A descending muscular branch to the diaphragm (*superior phrenic*), also termed, from its so constantly accompanying the phrenic nerve, the *comes nervi phrenici*. This branch accompanies the nerve in a tortuous manner, between the pleura and the pericardium, to reach the upper surface of the diaphragm, where it anastomoses with the phrenic arteries from the aorta.

3. The *anterior intercostal arteries.*—These are distributed to the six upper intercostal spaces; but their number is greater than that of the spaces for which they are déstined, as two branches are frequently found between adjacent ribs, and this arrangement may even prevail in all of these intercostal spaces.

The anterior intercostal arteries pass outwards in the intervals between the two planes of intercostals, in which muscles some of their branches terminate; others are lost in anastomosing with the intercostal arteries from the aorta, whilst many perforate the muscular fibres, and, arriving on the external surface of the thorax, dip into the pectoral muscles and the mammary gland. In both these latter situations the arteries in question communicate freely with the external thoracic branches of the axillary, thus forming an important connection between the circulation of the interior and that of the exterior of the thorax.

The *terminal branches* of the internal mammary artery are two in number, viz. *internal* terminal branch (*Ramus abdominalis*) and an *external* (*Arteria musculo-phrenica*, Haller).

4. The *internal*, or the abdominal branch, is the smaller of the two, yet in direction it represents the parent trunk. Having communicated with the artery of the opposite side behind the xiphoid cartilage, it escapes from the thorax through a small triangular interval between the fibres of the diaphragm, and then immediately enters the sheath of the rectus abdominis, descending between the muscle and the posterior lamina of the sheath. Having arrived opposite the umbilicus, it becomes distinctly continuous with ascending branches of the internal epigastric artery; it likewise furnishes many branches to the substance of the rectus muscle, and others which, piercing the sheath, are widely distributed to the broad muscles of the abdomen.

5. The *external* terminating branch (or the arteria musculo-phrenica), is larger than the internal, from which it separates nearly at right angles, passing almost transversely outwards in a curved course along the superior line of attachment of the diaphragm to the false ribs. In this course the artery gives off, *a.* numerous *phrenic* branches of large size, which enters the diaphragm all along its costal attachment; and *b. anterior intercostal branches*, which supply the *lower* intercostal spaces in precisely the same manner as those from the mammary trunk supply the *upper*, and which have been already described.

Varieties.— The mammary artery presents but few varieties either of origin or position; in 290 out of 297 examinations, this artery occupied its normal position. In one instance it arose beneath, in six instances external to the scalenus muscle, and in one only of the six was it derived from the axillary artery (Quain).

Much more rarely still does the mammary artery deviate in the opposite direction, i.e. *inwards;* it has, however, been seen to spring from the arch of the aorta, and also from the arteria innominata. Occasionally too it arises in common with the thyroid axis.

Two veins (one on either side of it) accompany each internal mammary artery; they are formed by branches corresponding to those given off by the artery, with the exception (according to Cruveilhier) of the vein accompanying the arteria comes nervi phrenici, which on both sides terminates separately. On the *right side* the mammary veins open into the commencement of the vena cava; on the *left side*, they are connected with the corresponding vena innominata. "The mammary arteries are remarkable for the number of their inosculations, and for the distant parts of the arterial system which they serve to connect: they anastomose with each other, and their inosculations with the thoracic aorta encircle the thorax. On the parieties of this cavity their branches connect the axillary and subclavian arteries; on the diaphragm they form a link in the chain of inosculations between the subclavian artery and abdominal aorta; and in the parieties of the abdomen they form an anastomosis most remarkable for the distance between those vessels which it serves to connect, namely, the arteries of the superior and inferior extremities."*

III. *Thyroid axis.* — This artery springs from the anterior aspect of the subclavian trunk, close to the inner edge of the scalenus anticus muscle, and consequently from the very last portion of the artery in its first stage.

The thyroid axis forms a trunk only a few lines in length, which projects forwards and a little upwards: the phrenic nerve is applied against the outer surface of this artery, and still retains the same relation to it, even where the artery arises more externally than usual, as if in such cases the nerve were drawn outwards by the artery. This arrangement was observed where the thyroid axis arose from the third stage of the subclavian. The thyroid axis usually terminates in three branches:—

1. *Inferior thyroid artery.*—From the thyroid axis, this branch passes a little upwards, and then turns inwards and backwards, describing a curve, of which the concavity looks forwards and downwards, corresponding to the carotid sheath. The artery next descends, but soon afterwards inclines upwards and inwards until it reaches the thyroid body, thus forming a second curve the reverse of the former one, for the concavity of this second curve looks upwards and backwards, and is crossed anteriorly by the recurrent nerve.

The *anterior relations* of this artery are the following:—

It is crossed in its first curve, opposite the sixth cervical vertebra, by the sympathetic nerve, which more frequently on the right than on the left side however, joins the *middle cervical ganglion* in this situation. The internal jugular vein, vagus nerve, and carotid artery, contained in their common sheath, are the next parts which cross the artery; and lastly, the recurrent nerve, sub-hyoid muscles, and thyroid gland, lie in front of it.

The recurrent nerve lies in front of the second curve of the artery.

The inferior thyroid artery is *posteriorly* in relation with the vertebral artery, the longus colli muscle, and the vertebral column; and, *on the left side*, with the œsophagus and thoracic duct.

The thoracic duct very frequently passes up behind the inferior thyroid artery to the level of the sixth cervical vertebra, where, bending downwards and forwards, it arches over that vessel and descends *in front* of it, to terminate in the subclavian vein.

* Harrison's Surgical Anatomy of the Arteries. 4th Edition, p. 141. Dublin.

Branches of the inferior thyroid artery. — *a. Arteria cervicalis ascendens.* — This branch (arising from the upper convexity of the thyroid, where that vessel changes its direction to pass downwards and inwards beneath the carotid sheath) passes upwards on the superficial surface of the scalenus anticus, parallel and internal to the phrenic nerve. The cervicalis ascendens (frequently as large as the thyroid itself) furnishes numerous *muscular branches* to the levator anguli scapulæ, longus colli, rectus capitis anticus major, and to the scaleni muscles, some of which anastomose with branches of the occipital artery; it likewise gives off *spinal* branches, which enter the spinal canal along the cervical nerves, and are distributed to the cord, anastomosing both within and without the canal of the vertebra with the vertebral artery.

By some anatomists the cervicalis ascendens is regarded as a branch of the thyroid axis, from which it not unfrequently arises; in some rare instances it has originated directly from the subclavian artery. Sometimes it is of very large size, and takes the place of the occipital artery or of the cervicalis profunda.

b. The inferior thyroid artery furnishes several *descending branches,* which from their destination may be termed *œsophageal, tracheal,* and *bronchial.*

c. Terminal or *thyroid branches.* — The inferior thyroid artery becomes extremely tortuous as it approaches the thyroid gland; at last it divides into two or three large branches, which enter the gland *by its deep surface,* and which, in the substance and around the margin of the gland, communicate freely with the corresponding artery from the opposite side, and with the superior thyroids of the external carotid.

The reader is now referred to the article Scapular Region, in which the remaining branches of the thyroid axis, viz. the *supra-scapular* and *transverse cervical* arteries, have already been followed to their ultimate distribution; it will be only necessary in this place to describe the *cervical* portions of these two collateral branches.

2. *Supra-scapular artery* (*Arteria transversalis humeri*). — This artery is at first directed downwards, but having reached the shelter of the clavicle, it passes nearly horizontally outwards to the superior costa of the scapula. It crosses over the phrenic nerve, the scalenus anticus muscle, and the subclavian vein; it then runs outwards in contact with the vein, and bound to it by cellular tissue; it next passes across the subclavian artery and brachial plexus of nerves, and finally arrives at the supra-spinal fossa, which it enters by passing over the superior ligament of the scapula.

The supra-scapular artery has, *anterior* to it, the sterno-mastoid muscle, the clavicle, and the omo-hyoid and trapezius muscles. It accurately corresponds to the base of the supra-clavicular space.

3. *Arteria Transversalis Colli.* — This artery is larger than the preceding; from its origin it passes transversely outwards over the scalenus anticus muscle and the phrenic nerve; at the outer edge of this muscle, it inclines backwards and runs through the midst of the branches of the brachial plexus. The artery at this stage crosses the summit of the omo-clavicular triangle, above the level of the subclavian artery. In the space between the sterno-mastoid and the trapezius, the transverse cervical artery gives off a large branch, the *cervicalis superficialis,* which is destined for superficial structures, integuments, platysma, glands, and superficial layer of muscles.

The *cervicalis superficialis* ascends in the posterior superior triangle of the neck, through a chain of conglobate glands, and through the meshes of the cervical plexus of nerves, anastomosing with branches of the occipital and vertebral arteries, and passing finally under cover of the trapezius, to which it distributes numerous twigs, as also to the levator anguli scapulæ and splenius.

After this the continued trunk of the transverse cervical artery is usually called *posterior scapular artery,* which has elsewhere been described.

The *posterior scapular,* and the *cervicalis superficialis* arteries, very frequently arise *separately,* instead of springing by a common trunk from the thyroid axis; in such cases the posterior scapular is usually given off by the subclavian artery external to the scaleni.

IV. *Arteria Cervicalis profunda.* }
V. *Superior Intercostal Artery.* } These arteries (as has been already mentioned) generally arise by a short trunk common to both, from the subclavian in its second stage. An analogy may thus be observed between this trunk and the aortic intercostal arteries; for, like them, it divides into an *anterior* or intercostal branch (the superior intercostal artery), and a *posterior* or muscular branch (the cervicalis profunda). The *cervicalis profunda* passes from its origin backwards and upwards, between the transverse process of the last cervical vertebra and the first rib. When a supernumerary cervical rib exists, the artery then passes between this latter and the first dorsal rib. It thus gains the posterior aspect of the neck, and ascends between the spinous and transverse processes of the vertebræ, separated from the laminæ by the deep layer of muscles, and covered by the great complexus muscle.

In this course the cervicalis profunda anastomoses with the large muscular branches which descend from the occipital and vertebral arteries.

The deep cervical artery sometimes passes backwards at a higher or lower level than that above specified; these deviations must be rare, since none of them existed in 40 subjects examined specially with reference to this subject by Cruveilhier. In the extensive tables collected by Professor Quain, and which have already been frequently alluded to in this article, seventeen instances are given where this artery passed between the first and second rib; in a very few examples, it escaped from the thorax through the second intercostal space, and in some other equally rare cases, it has been seen to penetrate between the sixth and seventh cervical transverse processes.

The *superior intercostal artery* passes downwards in a tortuous manner into the thorax, and gives off branches which run outwards and supply the two or three upper intercostal spaces; the artery of the right, usually passes to one intercostal space lower than that of the left side. The branch to the first intercostal space is in general the smallest.

The trunk of the superior intercostal artery, as it descends, has the following relations:—*in front*, it is covered by the pleura and lung; *internal* to it are placed the first dorsal ganglion of the sympathetic nerve, and the longus colli muscle; whilst *posteriorly*, it corresponds to the first dorsal spinal nerve (in its ascent to join the last cervical), and to the neck of the first rib.

In addition to the branches furnished to the intercostal spaces, and which are two or three in number, the superior intercostal gives off several small branches which enter the spinal canal through its lateral foramina, and also a branch which passes downwards and establishes a communication with the first aortic intercostal artery.

It has been already stated that the superior intercostal and the deep cervical arteries most frequently arise by a common trunk; when they arise separately, the left superior intercostal artery is generally derived from the first stage of the corresponding subclavian artery.

Operative proceedings.—It is not intended in this place to enter into all the details connected with the surgical relations of the subclavian artery, since in the article which treats of the surgical anatomy of the neck will be found clearly described the modes of procedure to be adopted by the surgeon in the operations for the ligature of this artery in different parts of its course; the following few observations, which may be regarded as supplemental to those just alluded to, naturally follow the description which has been given of the subclavian artery in the preceding pages.

First stage. — When the relations of the subclavian artery *on the right side*, internal to the scaleni muscles, are carefully reviewed, the *inner half* of this stage of the vessel will appear to be the most eligible for the application of the ligature, and the object of the operator should be to secure the artery on the cardiac side of its vertebral branch, as in that situation the pleura is comparatively little exposed to injury; the jugular vein should lie to the outside, and the vagus nerve to the inside of the ligature, and any undue disturbance of these parts, especially of the latter, ought to be most sedulously avoided.

The artery was tied, for the *first time* in this situation, by Mr. Colles, in the year 1813. In that instance, as in every subsequent one where the operation has been repeated, the result has proved unfavourable; nevertheless, success has been so nearly attained in some of these cases, that few will be found to agree with Blandin in pronouncing this operation "tout a fait irrationnelle;" nor are we to view with favour the alternative first suggested by Mr. Shaw, and lately revived and recommended to the profession in some recent works on surgery, viz., to remove the arm at the shoulder-joint, and to make pressure on the aneurismal tumour.

In the majority of the cases in which hitherto the subclavian artery has been tied internal to the scaleni, the cause of death was referable to secondary hæmorrhage; the unavoidable proximity of the ligature on the one hand to the heart, on the other to the aneurismal sac, and the small extent of this part of the subclavian artery to which a ligature can be applied, without interfering with the collateral branches, are probably the chief circumstances which determine this fatal accident. If, in the desire to avoid the vertebral, thyroid, and mammary branches, the ligature be applied too close to the mouth of the carotid artery, the current of blood through the latter vessel will then, with almost positive certainty, disturb those sanative processes at the seat of ligature, on which the ultimate success of the operation depends; and hence, doubtless, has originated the proposal to secure *at the same time* both branches of the innominata. The incisions necessary to expose the one, would amply suffice for the ligature of the other; the circulation through the head and upper extremity might afterwards be carried on without material injury, and the formation of a coagulum, *more lengthy* than that afforded by the operations hitherto performed, might lead to a favourable result. This suggestion is due to Dr. Hayden, and is mentioned in his account of the case in which he tied this artery in its first stage, so far back as the year 1835.

The following brief particulars of a case which lately came under the writer's notice, may be adduced as furnishing an additional argument in favour of this proposal. A woman, about 25 years of age, became the subject of an aneurism, situated at the root of the neck, which was regarded as originating from the arteria innominata. The subclavian and carotid arteries were tied at one and the same time, on the principle of Brasdor:—"On the fourteenth day after the operation, the ligature came away from the subclavian artery *without any hæmorrhage*, and every thing promised a favourable result, especially as the *pulsation in the tumour had quite disappeared.* On the sixteenth day, the patient, a woman of violent temper, had a quarrel with the nurse, when she jumped out of bed, seized a pillow and some books, and threw them at her: while making this exertion, hæmorrhage set in from the carotid." A renewal of the hæmorrhage proved fatal. On examination it appeared that "*perfect union had taken place where the ligature had been applied to the sub-*

clavian artery, but a small opening was found in the carotid from which the hæmorrhage had proceeded."

In this instance the innominata was healthy; but, a little to the left of the origin of that vessel, the aneurismal tumour, which was of a pyriform shape, sprung *from the arch of the aorta*, and thence passed upwards into the neck, in front of, and overlapping the arteria innominata. It is an extremely interesting circumstance connected with this case, "that the tumour was filled with a firm coagulum."

This is the only instance, as far as the writer knows, *in which a ligature placed on the subclavian artery, in its first stage, became detached without the supervention of secondary hæmorrhage*. In none of the cases where this artery *alone* was secured did this circumstance occur, much less in any of these instances did "perfect union," the result of adhesive inflammation, follow the application of the ligature.*

Until very recently it was thought that the ligature of the subclavian artery internal to the scaleni was feasible on the right side only, and this opinion of British surgeons originated perhaps in Mr. Colles' statement, that "this operation, difficult on the right, must be deemed impracticable on the left subclavian artery." Dr. Rodgers, of New York, has, however, lately succeeded in securing the left subclavian artery in its first stage. The result of this case does not verify the opinion of Velpeau, that "the operation would be much less dangerous on the left side than on the right," as the patient died of secondary hæmorrhage on the fifteenth day.

British anatomists will be little disposed to agree with Velpeau in such a prediction, and still less will they concur with him in thinking that it would be easier to tie the left subclavian artery than the right; on the contrary, the great depth of the left subclavian trunk from the surface, the short distance to which it rises out of the thorax, and the close connection of the veins and nerves with its anterior surface, must entitle this operation to the distinction of being one of the most difficult, whilst the peculiar and unseen risk of wounding the thoracic duct must ever render it one of the most dangerous, in surgery.

Second stage. — The subclavian artery has been tied between the scaleni muscles in a few instances. This operation was first performed by Dupuytren, in 1819, in a case of traumatic axillary aneurism; the result was successful; yet there is nothing in this operation to recommend it, provided there be the option of tying the artery in the supra-clavicular space. Dupuytren did not (as some have supposed) intend it to *supersede* the latter operation; he advised it in those cases only, where the depth of the vessel in its third stage is unusually great, in consequence of some peculiarity of development, or the unnatural elevation of the clavicle produced by an aneurismal tumour.

The *anatomical objections to this innovation*, which is sanctioned by the authority of Dupuytren, are the following, and they are sufficiently important to justify the conclusion that, where a choice exists, the third stage of the artery should always be selected for the application of a ligature.

1st That in order to expose the subclavian artery in its second stage, the division of two muscles is required, viz., the clavicular portion of the sterno-mastoid, and the scalenus anticus.

2d. That considerable risk of injuring the phrenic nerve is incurred.

3d. That the ligature must be in close proximity to the branches usually furnished by the subclavian artery between the scaleni, viz., the cervicalis profunda, and superior intercostal; and,

4th. That from its close connection with the artery, the cone of the pleura is endangered.

These theoretical objections to the ligature of the subclavian between the scaleni, are not the less deserving of notice because they were *originally* passed over in silence, and they go far to disprove the "*innocuité*" of the operation, an advantage which has been claimed for it by Dupuytren.*

The objections which have just been enumerated, are not however of sufficient weight to forbid a repetition of the operation in any case where insuperable difficulties are encountered in attempting to tie the artery in its third stage; under such circumstances, the surgeon would evince both skill and dexterity by dividing, as far as necessary, the scalenus anticus muscle, and thus accomplishing the object of the operation; and in so doing he would follow the example of the late Mr. Liston, who, in a parallel case, thus succeeded in securing the artery between the scaleni.

Where the *outer edge* of the muscle alone is divided, and where proper caution is used, the safety of the phrenic nerve is not necessarily compromised; but without very great caution in passing the needle, the pleura will suffer injury, as it is placed in close contact with the back of the artery. It should also be borne in mind, that the *phrenic nerve* has in a few instances been seen to pass down beneath the clavicle, lying *on the outer edge* of the scalenus anticus muscle; should such an anomaly occur in a person subjected to Dupuytren's operation, the nerve could scarcely escape from injury. This irregularity in the cervical stage of the phrenic nerve, has usually been seen in connection with a variety of origin of the axis thyroideus, which has been already adverted to.†

* The full details of this interesting case, which occurred in the practice of Dr. Hobart, of Cork, will be found in the forthcoming edition of "Flood's Surgical Anatomy of the Arteries," edited by Dr. Power, one of the lecturers at the Richmond Hospital School, to whom the writer is indebted for the facts already quoted.

* Vide "Leçons Oracles," tom. iv.; and M. Marx account of the operation in the "Répertoire Générale d'Anatomie," No. 2.

† It may be presumed that the phrenic nerve was thus unusually placed in a case which occurred in the practice of Mr. Bransby Cooper, and which he

In its *third stage*, the subclavian artery has very frequently been the subject of operation, and the ligature of the vessel in this situation, in a large number of the cases recorded, has been eminently successful. Mr. Ramsden, of St. Bartholomew's Hospital, in the year 1809, was the first who secured the artery in its third stage, and since then the operation has been successfully repeated by many surgeons, in this as well as in other countries.

Although the subclavian artery, above the clavicle, is covered by no muscular fibres except those of the platysma, yet it always lies at a considerable depth, which varies much in different persons; the statement of Dupuytren will generally be found correct, viz., " that the third part of the course of the subclavian artery is placed more superficially in those who have long, slender necks, with lean and pendant shoulders, but is, on the contrary, deeply hidden in persons who have short, thick necks, and muscular shoulders."*

It is an unfortunate circumstance that the disease for which the operation is usually undertaken, should so constantly be the cause of great difficulty in its performance, for an axillary aneurism of any considerable size cannot fail to elevate the clavicle considerably. This fact is well illustrated in the embarrassments experienced in a case where the subclavian artery was tied by the late Professor Todd, one of the surgeons of the Richmond Hospital, and which are recorded in the third volume of the Dublin Hospital Reports. So great have been the difficulties experienced in the operation, that on one occasion Sir A. Cooper was obliged to abandon the attempt, and on another (already alluded to) Mr. Liston was compelled to tie the artery between the scaleni, finding it impracticable to expose the vessel in its third stage.

(*B. Geo. M'Dowel.*)

thus narrates in his published lectures: "Some years ago I performed this operation (ligature of the subclavian artery in the supra-clavicular space) on a clergyman, in the presence of the late Dr. Babington and Mr. Travers; no difficulty whatever occurred, but immediately after its completion the patient was seized with a constant hacking cough, as if resulting from convulsive motion of the diaphragm. This scarcely ceased night or day until the sixth day after the operation, when he died. No post-mortem examination was permitted; but there can be no doubt, in my mind, that the phrenic nerve had been injured, although it could not possibly have been included in the ligature."—Vide Med. Gazette. Lond. Vol. xlii. p. 94. July, 1848.

* Leçons Orales, tom. iv. p. 528.

SUPRA-RENAL CAPSULES.

(*Die Nebenniere*, Germ. *Capsulæ suprarenales seu atrabilariæ*, Lat. *Capsules suprarenales, atrabilaires*, Fr.) — In the bodies of Vertebrata we find a series of organs, which possess a great outward resemblance to the glands, but distinguish themselves from these by the constant absence of a duct. To this class belong the spleen, the thymus, the thyroid, and the supra-renal capsules. On account of their great richness in blood-vessels, these organs have been named "blood-glands," or "glands of blood-vessels," or "vascular ganglia." At present we are tolerably acquainted with the range of their distribution, and the differences of their form in the animal kingdom; we have, also, some knowledge of their minute structure; but, on the other hand, their physiological import remains just as obscure to the inquirers of the present century as it was to the physicians of ages long gone by.

The *supra-renal capsules, glandulæ supra-renales seu renes succenturiati, seu capsulæ atrabilariæ*, form, in the higher Vertebrata, a double organ, which is constantly placed in the neighbourhood of the kidneys; and from this situation they have received their name. So, also, in the lower Vertebrata they often occupy the same situation; but, not unfrequently, they are broken up into a number of small glandular bodies. In the Invertebrata they are altogether absent.

We shall successively consider, 1. The larger series constituted by the differences of form of supra-renal capsules in the animal kingdom. 2. Their structure. 3. Their development. 4. Their physiological relations.

I. As already mentioned, supra-renal capsules occur only in the Vertebrata. But we cannot attribute them to all of these without exception. In the lowest Amphibia and Fishes, these organs have not yet been indubitably recognised. Among the Mammalia, the supra-renal capsules exhibit everywhere essentially the same structure, in spite of many differences of form, size, and situation.

In *Man* they possess a half-moon shaped, or triangular and flattened form, with an antero-posterior slightly arched surface, and a sharp convex margin. At their bases they are deeply excavated, so that by this part they rest on the upper end of the kidney like a cap. The anterior part of the basis of the supra-renal capsule extends for a considerable distance further forwards on the kidney than the hinder part. The whole organ is included in a covering which consists of closely woven areolar tissue; and inferiorly, it is attached by a looser areolar tissue to the kidney. At the base of the organ is also found a well-marked fissure, from out of which passes the supra-renal vein, according to Krause's statement.* The anterior and posterior surfaces of the supra-renal capsules exhibit an irregularly wrinkled appearance, caused by the numerous furrows of the areolar tissue. The size of the supra-renal capsules amounts in the adult to 1—1½ inches (German) in height, and somewhat less in breadth. The greatest antero-posterior thickness occurs in its lowest part, and amounts from 2½—4 lines. In their middle the supra-renal capsules are considerably thinner, amounting only to 1½—2½ lines. Their absolute weight is estimated by Meckel

* Vide Krause's Handbuch der Anatomie. 2. Auflage, Hannover, 1841. Band 1. S. 668.

to be one drachm: according to Krause * it is from 80—120 grains; according to Huschke† from 80—180 grains. The anatomist last named found that its specific weight in the newly-born infant was 1·0333; but Krause states the supra-renal capsules of the adult to be of the somewhat lower specific gravity of 1·0163.

The two supra-renal capsules of the same individual are generally of different size. Usually the right is of somewhat lesser height, but greater breadth, than the left, which has the contrary diameter the larger.

The so-called *accessory supra-renal capsules* are often found in man. They are small round corpuscles, which, in various numbers, are attached loosely to the inner border of the supra-renal gland, or are sometimes imbedded in an excavation on its surface.

The supra-renal capsules of the *Mammalia* essentially correspond with this description.‡ They are always situated on the upper part of the kidneys; sometimes towards the inner part, sometimes on the upper part of their border, as in man. Sometimes they are not so closely attached to the urinary organs as in man, but are somewhat more removed from them. Thus, for instance, are arranged the supra-renal capsules of the Elephant and Seal. But, in opposition to this constancy of situation of these organs, we find very considerable differences in respect of their size and form.

The supra-renal capsules of *Monkeys* closely approach the shape seen in the human subject; but, not unfrequently, their size seems somewhat more considerable. Among the *Carnivora* they are, in the Dog, of an elongated cylindrical form, sometimes thicker at the margin than in the middle, and of a dense solid texture. So also in the Cat, in whom they are roundish, and somewhat flattened. Amongst *Insectivora* they have in the Mole (*Talpa europæa*) the form of a three-sided pyramid. In the Seal they appear very small, and Cuvier found that their size was, to that of the kidneys, as 1—150. In this latter animal the whole surface of the supra-renal capsules is divided into a multitude of lobules, or acini. Amongst all the Mammalia, these blood-glands are largest in the *Rodentia*, their ratio to the kidneys being as 1 to 4 and 5: this is the case, to wit, in Cœlogenys Paca, and in the Guinea-pig (*Cavia cobaia*). They are roundish, and somewhat flattened, in the Rabbit and the Dipus. The supra-renal capsules of the Mouse, the Rat, and the Myoxus Glis, have a shorter form; while, on the other hand, in Hystrix they become more cylindrical.

* Loc. cit.

† Huschke, Lehre von der Eingeweiden und Sinnesorganen des menschlichen Körpers. Leipzig, 1844, S. 357.

‡ Concerning the differences of form of the supra-renal capsules may be consulted the well-known text-books on comparative anatomy of Cuvier and Meckel; and, especially, Nagel in Müller's Archiv for 1836, S. 365., and Ecker, Die feinere Bau der Nebennieren, Braunschweig, 1846.

Amongst the *Pachydermata* they have, in the Elephant, the form of an elongated cone, and their base is divided into two lobes, and turned backwards. In the Pig, their form is about midway between the cylindrical and the prismatic. Besides this, the supra-renal capsules of this animal possess a considerable size. In the Horse they are flattened and triangular, approaching the human form. Among the *Ruminantia* they are, in the Rein-deer, of an oval form, which approximates to the spherical. They are elongated in the Sheep. In the Ox, their shape in some degree resembles that of the kidney. Here they are almost crescentic, not unlike a horse-shoe, and their upper extremity is three-sided. Finally, the supra-renal capsules of *Cetaceans* are, like those of the Seal, exceedingly small, and broken up into a number of small lobes.

We find a similar correspondence in the class of *Birds*. Their supra-renal capsules are generally small in proportion to the size of the body; sometimes spherical, sometimes oval; and, in general, divided into lobules. They lie at the inner extremity of the anterior part of the kidney, often close to the inferior vena cava; and they are covered by the testicles, or ovaries.

In the *Reptilia* these organs are much less known, since only isolated (and not unfrequently contradictory) observations have been made respecting them. Hitherto they have not been found among the Derotremate, Perennibranchiate, and Cæcilian orders of this class.

The supra-renal capsules of the *Saurians* have been very eagerly examined, and most exactly in the genus *Lacerta*. In these animals Nagel found them along the upper extremity of the vas deferens, in the form of two long, small, lobulated bodies. Nagel's observations have been recently confirmed, and added to, by Ecker. The supra-renal capsules, possessing the form stated by Nagel, have a length of $1\frac{1}{4}$ lines, with a breadth of $1\frac{1}{2}$. They lie closely on the vena renalis revehens, or on the vena cava ascendens, which is constituted by the two efferent renal veins. Since the right supra-renal capsule is usually of somewhat larger size, it is wont to lie on the vena cava itself; while the left organ is placed upon the vena renalis revehens. In the male lizard the supra-renal capsules are placed between the vein and the vas deferens; in the female they are situated between that vessel and the ovary. Numerous blood-vessels convey the blood from it into the corresponding veins. The blind worm (*Anguis fragilis*) also possesses long, small, supra-renal capsules; and so, probably, do the *Crocodilus Lucius* and *Ameiva teguixin*. Nevertheless, both the latter animals are at present insufficiently examined.

The supra-renal capsules of the *Ophidia* exhibit a similar condition, the more exact knowledge of which we especially owe to Retzius. They form two long and small bodies, and in the Python binistatus they attain a length of 8 lines. The supra-renal capsules of serpents are likewise distinctly lobulated, and very vascular. In other respects, too, the arrangement of the vascular system exhibits much that is interesting; but to this we shall hereafter return. They always lie closely on the venæ renales abducentes; and, according to the course taken by the vessels just named, they are sometimes nearer, sometimes farther from, the testicles and ovary.

Batrachia. Formerly many zootomists regarded as supra-renal capsules those peculiar yellow finger-shaped masses of fat, which, in these animals, lie superficially to the kidneys, and possess a connection with the sexual organs, in the periodical increase of which they take a share. Only recently have the true supra-renal capsules been recognised; and to these the fatty bodies just mentioned have not the remotest resemblance. To Rathke *, Retzius †, Gruby ‡, and others, we owe the discovery and description of these organs; the signification of which receives an additional and complete confirmation from minute anatomy, as will be hereafter shown. Here the supra-renal capsules no longer form an organ anatomically defined, but are immediately deposited on the abdominal surface of the substance of the kidneys.

Among the tailless Batrachia, they appear in this situation as a golden-yellow streak, which does not extend the whole length of the kidney, but ceases at a distance of one line from its upper, and of two lines from its lower, end. These supra-renal organs also allow a lobular composition to be very distinctly discerned; and they do not extend along the kidney in a straight line, but usually digress into the arched form. They surround the trunks of the efferent renal veins at their exit from the substance of the kidney; so that they seem to be, as it were, perforated by this vessel. By a more careful investigation one may satisfy one's self that the glands are really imbedded in the coats of these vessels. In the tailed Batrachia, on the other hand, we no longer find the supra-renal capsules in the shape of this connected streak, but broken up on all sides into from twenty to thirty separate and irregular lobules. These are seated, partly in the substance of the kidney at its inner border, partly between the kidney and the inferior cava; while they are also partly deposited on the coats of the latter vessel, and the gland-lobules have the same relation to the efferent renal veins as in the tailless Batrachians.

Finally, amongst all the orders of *Reptilia*, the supra-renal capsules are least recognised in the *Chelonia.* The statements formerly made by Bojanus §, that the supra-renal capsules were two long bodies, situated at the inner margin of the kidneys, and a similar statement of Nagel *, have been lately corrected by Ecker.† According to the last inquirer, the supra-renal capsules of the *Testudo græca* altogether correspond, both as regards form and situation, with the similar organs of the Frog; since they lie on the abdominal surface of the kidney, imbedded in its mass, and extend almost the whole length of this organ.

In *Fishes* the supra-renal capsules again appear; but, as regards their situation, form, and number, they are much more diverse than in the other Vertebrata. The supra-renal organs of the cartilaginous fishes were discovered, a long time ago, by Retzius.‡ For a knowledge of them in the osseous fishes, we are especially indebted to Stannius and Ecker.

In the *osseous* fishes they appear as small, whitish corpuscles, of the size of from a pin's head to a pea. Their form is, in general, roundish or oval; their surface is sometimes smooth, sometimes rugged, and broken up into lobules, as is the case in the Pike. According to the observations of Stannius, they have not unfrequently a kidney-shaped form in the Haddock; and, according to Ecker, they are sometimes triangular in the Salmon.

The number and situation of the supra-renal capsules varies greatly in this group of fishes. The presence of two supra-renal capsules ought to be regarded as the rule. They usually lie symmetrically in both halves of the body, as in the higher animals; they may also occur a-symmetrically, or only in one half of the body, as in the genus Pleuronectes; or they may be behind each other, as in the genus Scomber.

But frequently, the supra-renal capsules are present in great number; in which case their position becomes altogether irregular. Thus one meets with three, four, six, or even more supra-renal organs; and Ecker has observed as many as six in the Salmon. In the Pike, in which only two to three supra-renal capsules are present in the adult animal, the inquirer just mentioned found that, in a young animal of one foot in length, the whole kidney was beset with a great number of very small supra-renal organs. I have myself remarked the same condition, and occurring exactly in the manner described, in two Pikes of the same size: but, on the other hand, in another instance it was absent.

As to the situation of the supra-renal organs in the bony fishes, this also is subject to very great differences. Sometimes these glands lie more on the abdominal, sometimes on the spinal, surface of the kidneys. The former seems more frequently to happen; and in this case they generally project at the hinder end of the kidney, from the anterior margin of the hæmal canal of the inferior

* Beitrage zur Geschichte der Thierwelt, Dritte Abtheilung, Halle, 1825, S. 34.

† Vide the treatise of Nagel.

‡ Annales des Sciences Naturelles. Zoologie, Seconde Série, tom. xvii. p. 209.

§ Anatome Testudinis, Wilnæ, 1819—21. Folio cum tab.

* Loc. cit.

† Loc. cit.

‡ Observationes in Anatomiam Chondropterygyiorum. Lund. 1819, 4to.

vertebral arch: this occurs in the genera Cyprinus, Tinca, Pleuronectes, Anarrhichas, Scomber. Or they occupy more the middle of the kidney, as in the Salmo Salar. On the other hand, they are found on its abdominal surface in the Eel and Pike. They lie in this situation very anteriorly, occupying, in the Eel, the place where the two crura of the renal mass unite. In the Pike they are yet more advanced forwards, so that they come to lie in the middle point of the length of the body.

Amongst the *cartilaginous* fishes, the supra-renal capsules seem in the Squalidæ to be only present as a single mass. This, in the shape of a small ochre-yellow stripe, occupies the dorsal surface of the kidneys. But in the Rays the supra-renal organs form a curved cylinder, which is constricted at two points, and lies on the ureters; at least Retzius formerly stated this to be its condition. Stannius sometimes found in this genus a similar elongated body behind the kidneys: or, in other instances, four or five small glandular corpuscles were present in its place. And the latter observer found that the supra-renal glands of the Sturgeon* consisted of similar corpuscles in much larger number.

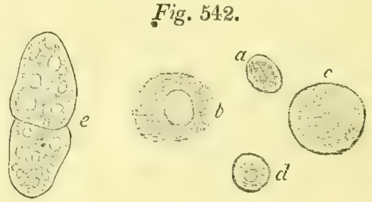
The supra-renal capsules of the cartilaginous fishes have a yellow colour, and are also plainly lobulated.

As has been previously remarked, in the least developed fishes the supra-renal capsules have not been discovered, at least not with any certainty, so that their existence must remain a matter of doubt. In the *Myxinoid* fishes, J. Müller† found behind the gills, and on each side of the cardia, a clustered gland which was devoid of an excretory duct. He interprets it as a supra-renal organ; and regards as analogous to it the white specks with which the trunks of the posterior veins of the body are beset in the Ammocætes.‡ But the minute structure of the glands in question in the Myxinoid fishes, which is also described by Müller, seems rather to contradict the explanation attempted. And Ecker discovered a gland in the Petromyzon between the aorta and the great vein of the body, and partly lying in the coat of the latter: but this also had not the structure of a supra-renal capsule.

II. We next proceed to the *minute structure* of the supra-renal capsules, concerning which Ecker has given a very good and fundamental description, so that we shall here in great degree follow him. In Man and all the Mammalia, they exhibit two kinds of substance, which have been designated by the names of *cortical* and *medullary* substance. The first is clearer than the latter, being in Man of a yellowish-brown colour; while the medullary substance possesses a reddish-brown hue. In many instances, the two kinds of substance are little distinguishable by the naked eye, so that the supra-renal capsules exhibit only a simple mass, such as Cuvier has described that of the Elephant to be. Besides this, the amount of the two layers varies very considerably. The cortical substance is of some solidity; while, on the contrary, the medullary matter is very delicate and flaky. This great delicacy, together with its considerable richness in blood-vessels, makes it very probable, that the medullary substance of the supra-renal capsules is decomposed very quickly after death. And this gives rise to the formation of a cavity, containing a brownish-red fluid, which is not unfrequently found in the interior of the human supra-renal capsules. Formerly this cavity was regarded as normal and occurring during life. The name "capsulæ atrabilariæ" is connected with this notion, since these cavities were described as real by the older anatomists. And although decomposition is regarded as the chief agent in the formation of these cavities, yet pathological conditions seem to be by no means without their influence towards them. Thus Rayer tells us the development of cavities may occur in consequence of rupture of the venous coats, and the effusion of blood in the medullary substance.* Nagel also remarks concerning it, that the supra-renal vein alone, which courses in the centre of the organ, may be instrumental to the production of such a cavity, albeit a small one; so that by injections through this vein the whole medullary mass may frequently be torn up, and converted into a cavity. The covering of the supra-renal capsules consists of areolar tissue. At many points of this covering little processes of areolar tissue pass directly into the interior of the medullary substance, and thus separate it into portions or lobes of different form and size. These masses of areolar tissue are finally lost in fine bundles, which separate the elementary parts of the gland from each other. We shall return to this again.

The further composition of the organ which we are now contemplating is better seen in Man than in any others of the Mammalia.

Fig. 542.



(*After Ecker.*)

a, Nucleus of the contents of the supra-renal capsule from an adult man; *b*, Nucleus enwrapped in a fine granular mass; *c*, Cell; *d*, Nuclear-vesicle of an embryo; *e*, two gland-vesicles with their contents from an adult.

* Stannius, Lehrbuch der Vergleichender Anatomie der Wirbelthiere, Berlin, 1846, S. 118.

† Vergleichende Anatomie der Myxinoiden. Schluss. In der Abhandlungen der Academie der Wissenschaften zu Berlin, 1843, S. 118.

‡ Rathke, Beitrage zur Geschichte der Thierwelt, 4te Abtheilung, S. 99.

* Gazette Medicale, 1838, p. 57.

In man the *cortical* substance appears to be composed of an innumerable quantity of completely shut glandular vesicles, which are united into a mass by the ensheathing coats previously mentioned. At the first glance one might easily imagine that they were not gland-vesicles, but tubes which, lying close to each other, take a radiating course from the centre towards the periphery. It is only at either margin of the cortical substance that the individual small roundish vesicles can be verified. By more careful examination, we can assure ourselves (as was first stated by Ecker) that this tubular appearance is only apparent, and that it is caused by the glandular vesicles being arranged in rows, so as to cover each other like the tiles of a roof. In this manner the vesicles of a row, especially when they are filled with dark contents, appear like a tube, with a blind termination at each extremity. The observation just mentioned can be best made if the preparation be treated with a dilute solution of an alkali. It will be thus seen that these vesicles of the supra-renal capsules are surrounded by and constructed of a fine, structureless, transparent membrane, to the thickness of which we are unable to assign any measurement, and which, even by the use of the highest magnifying powers of the microscope, appears as only a simple line. This structureless membrane, which modern observers have shown to be a constituent of all glands with the single exception of the liver, we shall indicate by the name of the "*membrana propria*." It is especially distinguished by the fact, that it is not attacked by the dilute alkalies, as caustic potash, and ammonia, but preserves exactly its original appearance; while the contents of the gland are in general completely dissolved by these agents. The use of these applications cannot be too much recommended in examining the glands, as for instance those of the stomach, intestine, &c.—a fact which has been taught me by repeated experiments. The gland-vesicles of the human supra-renal capsules exhibit considerable differences of size; besides which, their form is wont to vary in some degree. The smaller vesicles are roundish, and have a diameter of 8 to 12-1000ths of a line; the larger of these, which seem elongated, have a length of 18 to 25-1000ths of a line, with a breadth of 10 to 15-1000ths. The smallest of these vesicles occur in the greatest numbers at the limits of the medullary substance; while, on the contrary, the larger and more elongated vesicles generally occupy its middle. The glandular contents, which are surrounded by the vesicles, appear, by a low magnifying power, as a dense pap-like mass, which seems to be white by reflected, and dark by transmitted light, and consist of granules. Nevertheless on the application of a powerful lens four constituents may be distinguished; namely,—(1) very fine molecules, (2) fatty granules, (3) nuclei, and finally, (4) cells in different stages of their development.

(1) The fine elementary granules constitute by far the great mass of the contents. They are dissolved by alkalies, but alcohol and ether do not effect their solution, and they are little dissolved by acetic acid; so that they would thus seem to consist of an albuminous substance, or of a so-called protein-compound. They are immeasurably minute, and in this respect resemble the pulverulent molecules which cause the white colour of the chyle.* Their quantity in the gland-vesicles is so large that they render viscous their fluid contents. It is only on the application of water, that they aggregate themselves into masses or flocculi: previously to this they pervade the viscid fluid with the greatest uniformity. We will select for them the name of pulverulent molecules.

2. The fatty granules are usually met with in considerable quantity, and sometimes they are very numerous. As may readily be imagined, they are of very different diameters, and range gradually from the smallest granules, through larger ones, to small drops of fat. The yellow colour of the cortical substance is due to this constituent.

3. The nuclear structures appear united into a granular mass. They have an average size of 3 to 4-1000ths of a line, a form which is usually roundish and less frequently oval, and they belong to the variety of the so-called "granular" nuclei; *i. e.* to those which are formed of a granular mass, and are not vesicular. The substance of these nuclei is insoluble in dilute acids, but is completely dissolved by the application of potash. Ecker has made the interesting observation, that in the embryo the granular nuclei are no longer to be met with, but that their nuclei are rather vesicles; that is, that they possess a wall, which encloses a more or less fluid mass, in which are contained one or two small punctiform nucleoli. The same condition also obtains in the nuclei of other embryonal tissues.

4. Part of these nuclei are experiencing a transition to cell development, so as to form a constituent of perfect cells. The metamorphosis to the cell-form begins by a part of the finely granular mass arranging itself around a nucleus. Little clusters are thus formed, each of which contains a nucleus. The outer surface of such a mass then becomes hardened, so that the most superficial molecules form a wall or shell, the *cell-membrane;* thus the cluster becomes a cell. So that from the fine pulverulent molecules proceed both the cell and the cell-membrane. In conformity with this statement, a microscopic examination of the expressed contents of the gland-vesicles reveals nuclei, surrounded by irregular flocculi of fine granular substance (*b*, *fig.* 542.), and other nuclei, around which this latter substance has formed itself into a well-defined, round, or oval mass of 6 to 9-1000ths of a line in diameter (*c*, *fig.* 542.). Finally, other masses

* Compare with this the experiments of H. Müller, in Henle und Pfeuffer's Zeitschrift für rationelle Medizin, 1845, iii. S. 299.

may be seen, on which an enclosing membrane plainly exists.

The cell development just described holds good of the supra-renal capsules of all Vertebrata. It is thus of very wide distribution. These cells are designated by the name of globules of circumposition (*umhullungskugeln*). The so-called granule-cells, or inflammatory globules, belong to the same class; as also do the globules of fission which originate from the breaking up of the yolk. And I have also observed that the polyhedral pigment cells of the choroid coat of the eye are formed in the same way. Finally (and of immediate interest in this place), I have found that the cells of many other glands are similarly formed; namely, the cells of the tubular gastric glands, the glands of Lieberkuhn and of the large intestine, the glands of Brunner, and probably also those which occur in the urinary tubules of the kidney. It may also be conjectured that the cells of other glands will be found to originate in the same way.

By a gradual enlargement these cells of the cortical substance are metamorphosed into *gland-vesicles* (*e*, *fig.* 542.); so that while in the large gland-vesicles cells and nuclei occur in numbers, the smaller ones contain only a solitary nucleus. These smallest gland-vesicles are no way distinguishable from the larger cells; they also are cells, and the glandular contents are exactly those of the cell, and the membrana propria is identical with the cell membrane. The contrast between these vesicles and cells — a contrast upon which Ecker has laid particular stress — is of little importance. According to this observer, the membrana propria of the vesicle is unchanged by solution of potash, while, on the contrary, the membrane of the cell is dissolved by it. But by a repetition of the experiment one may be assured that it is only a dilute solution which leaves the membrana propria unaffected, and that by a more concentrated solution it is dissolved just as much as the cell-membrane. The difference is thus only quantitative, and is in exact conformity with the gradually increasing hardness of the membrane.

When fine sections of the *medullary* substance of the human supra-renal capsule are examined with the aid of the microscope, it is seen to be considerably clearer and more transparent than the cortical substance; a circumstance which essentially depends on the fact, that the fatty granules occur more sparingly in the former than in the latter. In Man, and in most of the other Mammalia, it is rendered very distinguishable from the cortical substance by the absence of the gland-vesicles. It is found to consist of a basis of fibrous tissue, which is formed by processes that come off from the sheath of the cortical substance, and in which numerous blood-vessels and nerves take their course. In the mass of areolar tissue the pulverulent molecules above described are also met with; and besides these, nuclei and cells in different stages of development.

Where *accessory* supra-renal capsules occur, they contain, according to Ecker, the same vesicles; of which the larger occupy the outside, and the smaller the inside. But the two kinds of substance are not present; the whole tissue answers to the cortical substance of the real supra-renal capsules, and it has a sometimes clearer, sometimes darker, yellowish appearance.

The structure just described obtains with little modification in all the Mammalia. It is true that, at present, only the Carnivora, Ruminantia, Solipeda, and Pachydermata, have been examined. Nevertheless, according to these observations, it is tolerably allowable to generalise concerning all the orders of Mammalia.

In the Ox, the brown cortical substance is divided by strong bundles of areolar tissue into lobules. The gland-vesicles exhibit nothing extraordinary, but, amongst the different constituents of their contents, the fatty granules are much more sparingly present than in man. Gerlach* found the glandular vesicles very distinct in the Sheep. The structure of the supra-renal capsules of the Goat and Pig is identical with that seen in the Ox.

In the Horse, the gland-vesicles of the cortical substance altogether correspond with those of the human subject. Here also the smaller and more spherical lie on the exterior, while the larger and more oval occupy the interior, and offer the tubular disposition already referred to. But their membrana propria is more delicate than in man. In the young Horse the fatty contents of the gland-vesicles are in very small quantity; while, on the other hand, in older animals, it predominates so considerably that it quite conceals all the other contents, and renders their examination very difficult.

But the medullary substance in the Horse offers a remarkable distinction from that of the other Mammalia: namely, that it, as well as the cortical substance, contains gland-vesicles. These have a variable shape and size; and are round, oval, elongated, or sometimes curved in the shape of a bow. The contents are the same as usual, only it is much poorer in fat than the cortical substance; and, on this account, appears much clearer.

The supra-renal capsules of the Rodentia and Carnivora possess the greatest quantity of fat, and are therefore the most difficult of examination.

Notwithstanding this, the white cortical substance of the Rabbit exhibits the usual arrangement: and, besides this, the medullary mass not unfrequently presents small circumscribed collections of fat.

Among the beasts of prey, the Dog and Cat have been examined, and in these the nuclei of the contents are with difficulty discoverable, owing to the innumerable quantity of the fatty molecules. The nuclei are here also granular in the older, vesicular in the younger

* Handbuch der Gewebelehre des Menschlichen Korpers, Mainz, 1849, 2tn Lieferung.

animals. A portion of fat not unfrequently surrounds the cells of the glandular contents; and in this manner large dark globules originate, which completely obscure the enclosed cell. These may especially be seen in the Cat, where they take a clustered arrangement and occupy the limits of the medullary and cortical substance. The medullary substance is poor in fat. Hitherto the gland-vesicles have not been made out with certainty in this fatty cortical substance, but they are very distinct in the Hedgehog.

It yet remains to us to consider the disposition of the blood-vessels, lymphatics, and nerves in the supra-renal capsules of the Mammalia. For this purpose we shall select those of Man.

Vessels. — In the human subject, each supra-renal capsule is supplied with arterial blood by three trunks:—by an *arteria supra-renalis superior*, which is usually present, and comes off as a branch of the phrenica inferior; an *arteria supra-renalis media*, which is usually *double* on each side, and arises from the aorta; and finally, an *arteria supra-renalis inferior*, which is a branch of the renal artery. The further arrangement of the vascular system has been especially examined by J. Müller *, and Nagel †, whose results have been recently confirmed by Ecker. ‡

The numerous small arterial trunks having arrived at the outer surface of the supra-renal capsules, take a different distribution. One part of them immediately pierce the sheath of the organ, and enter its substance; while another portion of them courses for a considerable distance on the outer surface before becoming lost in the interior.

In the interior of the organ itself these small arterial trunks still take a different course. One of these sets of vessels can only be followed for a very short extent in the cortical substance. After a course of scarcely half a line in length, they break up into a capillary network, with long meshes, which encircle the gland vesicles of the cortical substance. The other arterial trunks, without giving off any branches, plunge at right angles through the cortical mass into the medullary substance. Here they break up into twigs which, by devious paths, return again into the cortical mass, to end also in a network of capillary vessels. Thus the cortical substance possesses a closer capillary network than the medullary mass, a fact which is in conformity with the predominant glandular activity of the former stratum. Nagel, in his Essay, has illustrated this distribution of the arterial vessels by beautiful drawings.

The *veins* begin at the common margin of the cortex and medulla. They alone constitute almost all the vessels of the latter portion, since the smallest branches gradually unite to form larger ones, and these finally join to form the *vena supra-renalis*, which occupies the middle of the supra-renal capsule; and, as was stated above, is proportionally very large. "Were we able," says Nagel, "to exhibit this venous texture isolated from the cellular tissue which receives it, the individual smaller veins opening into the venous trunk on all sides, and at very acute angles, would render it most suitably comparable to a poplar tree."

Usually there is a single *vena supra-renalis* for each supra-renal capsule. The right supra-renal vein passes immediately from the gland into the vena cava ascendens; but the left one forms a longer trunk, which opens into the renal vein. But these statements of Nagel are contradicted by others; for instance, by Krause, according to whom two or three veins generally leave each supra-renal capsule.

As far as observations have hitherto gone, this disposition of the vascular system appears to be tolerably constant for all the Mammalia.

The *lymphatics* of the supra-renal capsules are not yet sufficiently known. According to Arnold, there are superficial and deep ones. In animals slain during the digestive act, Ecker could only find the superficial lymphatics, so that Arnold's statements would seem to be doubtful. The absorbent trunks of the supra-renal capsules unite with those of the kidneys and the internal sexual organs, and they open into the thoracic duct.

The uncommonly rich supply of *nerves* possessed by the supra-renal capsules constitutes a very striking phenomenon, and one which finds no parallel in any cognate organs. In Man, these nerves arise from the cæliac and renal plexuses in the form of numerous and proportionally large trunks. It is chiefly through Ecker that we have become acquainted with the further course of the nerves in the interior of the organ. Larger and smaller branches of nerves perforate the cortical substance, usually contained in the bundles of its areolar tissue, or accompanying its arterial vessels, but giving off no primitive fibres. Only in the medullary substance do the trunks of nerves break up into bundles of fibres. The neighbouring bundles often exchange their nerve-fibres with each other, so that, in this way, they form a dense microscopic nervous tissue. It would seem that, in the human subject, no ganglion corpuscles are present in this sympathetic nerve tissue; but, in the Horse, in whom the supra-renal corpuscles are yet richer in nerves than they are in man, some ganglion corpuscles may be seen on the nervous trunks of the tissue. But one must be especially careful against confounding gland-cells of the organ with these ganglion corpuscles, which they superficially resemble. This rich supply of nerves seems only to pertain to the supra-renal capsules of the Mammalia; in all the other Vertebrata, whose supra-renal capsules, as will be forthwith stated, are very similarly constituted, it is completely wanting. On this account, it becomes exceedingly difficult to state what

* Hildebrandt's Anatomie, herausgegeben von E. H. Weber, 4ter Theil, S. 356.

† Loc. cit.

‡ Loc. cit.

object is fulfilled by this united condition of the nerve fibres.

In *Birds*, the structure of these vascular glands is even more uniform than in the preceding classes. No separation into cortical and medullary substance appears to occur in any bird. A single observation of Meckel's states that in the Cassowary the two kinds of substance are to be distinguished; but this statement is contradicted by the numerous negative observations of Cuvier, Ecker, Bardeleben, and Nagel, on all the animals of this class which they have examined, and hence it requires a confirmation. The supra-renal capsules of birds appear of a darkish or clearer yellow colour, which, by the varying amount of blood they contain, tends more or less towards red. They are also enclosed in a sheath of areolar tissue, and exhibit a basis which consists of fibrous tissue and blood-vessels. In this matrix the gland-vesicles lie imbedded throughout the whole thickness of the organ, and they are devoid of any regular arrangement. They are of roundish, oval, pear-shaped, or irregular form. Their size varies from 44 to 56-1000ths of a line, and in the Falco tinnunculus some of them even attain the size of 22-100ths of a line. Their membrana propria is very delicate. The structure here specified may be best witnessed in the supra-renal capsules of large birds; nevertheless, with some care, we may succeed in recognising the gland-vesicles in the smaller members of the class, as, for instance, in the Pigeon.

The contents of their gland-vesicles closely resemble those of the Mammalia. There are the same fine pulverulent molecules of a protein compound; and fatty granules, which are usually in very large quantity, have a yellowish colour, and give rise to the tint possessed by the whole organ. Not unfrequently larger yellow drops of fat are visible. Besides these, we come upon the granular nuclei previously mentioned, possessing a size of 22 to 31-10,000ths of a line. Some of these nuclei are also enveloped in a fine granular mass, and exhibit a transition to cells in the mode which we witnessed in the Mammalia. Not unfrequently the nuclei are completely buried in fatty granules, through which they are only visible as clear spots. In the golden Eagle Ecker remarked complete cells filled with fatty granules; these were probably caused by the usually finely granular cells becoming gradually filled with fat. In many of the gland-vesicles, on the contrary, the fat is remarkably diminished in its proportion to the finely granular substance; and it has been conjectured by Ecker, and with great probability, that this difference in the amount of fat depends upon the different stages of development of the gland-vesicles. In a very young Pigeon I have found scarcely any fat molecules, a fact which has some connection with this statement.

The minute anatomy of the supra-renal capsules of the *Reptilia* is as yet insufficiently known.

In the supra-renal capsules of Lacerta agilis, Ecker was with some difficulty able to recognise the same condition as that seen in the higher Vertebrata; but the presence of a membrana propria around the gland-vesicles was especially indistinct. He only remarked masses of a darkish substance. These masses consisted of fatty granules of the nuclei already described, and of granulated globules, which contained a nucleus, and possessed a size of 31 to 44-10,000ths of a line.

In the Adder, the obscurity of the contents uncommonly aggravates the difficulty of examining their lobulated supra-renal capsules; but in the fœtal Adder of three inches length, Ecker was able to verify the separate gland-vesicles in the usual manner. Here also nuclei were seen; and, besides these, large pale gland-cells, which could not long resist the action of water. Other cells were completely buried in fatty masses, just as they were seen to be in the carnivorous Mammalia.

The arrangement of the vessels of the supra-renal capsules is peculiar in the Snakes, inasmuch as the greater part of the blood is not brought to the organ by means of arteries, but by veins. In consequence of this, the supra-renal capsules have a kind of portal venous system, such as is possessed by the kidneys of Reptilia and the liver of Vertebrata. The afferent supra-renal veins arise by two branches from the wall of the body, and from the plexus venosus of the vertebral canal; and after a tolerably long and isolated course they reach the supra-renal capsules. On an average, the right supra-renal capsule receives two or three branches; but the left, which is wont to be smaller, only one or two. The arterial blood is brought to the supra-renal capsule by one or two vessels which are branches from the aorta.

Both kinds of vessels ramify in the substance of these organs, so as to form a fine capillary network. The efferent supra-renal veins arise from this network in the form of numerous small trunks. They pass from the right supra-renal capsule immediately into the vena cava posterior; but from that of the left side into the inferior cava, and also into the efferent renal vein.

In his examinations of the Testudo græca, Ecker found certain bodies, which he regards as the supra-renal capsules of the *Chelonian* reptiles. By microscopic examination, they appear as yellow granules which are grouped together in heaps. Each of these is enclosed in a membrana propria, and thus constitutes a gland-vesicle. Their contents are altogether identical with those of the Batrachia, to which we shall next apply ourselves.

In the tailless *Batrachia*, the yellow lobules already described consist of groups of vesicles. Their form varies; sometimes it is round, sometimes oval, sometimes elongated or irregular. The vesicles are always closed, and it is only when they are grouped together that they appear at first sight like blind sacs. Fatty granules constitute the greater part of their contents; but besides these, the fine granular substance is also present. Clear spots may also be seen glimmering from amidst the contents of the gland, and isolation shows these to be cells of 5 to 9-1000ths of a line in diameter, with finely granular contents and a nucleus. The application of water renders this more visible. Part of these cells are devoid of the cell membrane, but others of them exhibit it very distinctly. Besides these, free nuclei are found; these are sometimes vesicular and contain a nucleolus, sometimes they appear to be granulated. The nuclei which are included in cells are always of the latter kind.

From these microscopic characters of their contents exactly corresponding with those of the higher Vertebrata, the import of these organs as supra-renal capsules is placed beyond all doubt.

The same structure obtains in the tailed Batrachians, only the nuclei and cells are larger, while a part of the latter are completely enclosed in fat. Numerous branches of the afferent renal veins break up anew in the supra-renal capsules, in order to provide it with venous blood, a condition which reminds us of that seen in the Snakes.

The minute anatomy of the supra-renal capsules of *Fishes* is very similar. In the Salmon Ecker found them consisting of separate lobules, which are deposited in a loose areolar tissue perforated by vessels, and which, in addition, receive a special covering of this areolar tissue. Each lobule is composed of a number of large gland-vesicles, from 5 to 11-100ths of a line in size, which are surrounded by blood-vessels. Their membrana propria is completely structureless. In their contents we again recognise the pulverulent molecules, separate fatty granules, and vesicular and granular nuclei of 2-1000ths of a line in size. The granular substance is rolled around these nuclei in the manner before described; so that part of them come to notice as spheres without walls, while part are real cells, surrounded by a membrane, and of 7 to 9-100ths of a line in measurement. It is not unfrequent to find two or three nuclei, instead of one, in their interior. We have remarked an exactly similar condition in the supra-renal capsules of the young Pike; there is the same fibrous coat, giving off processes which pass into the interior, and thus isolate the gland-vesicles, but the supra-renal organs are less divided into lobules than in the fish previously contemplated. The contents of the gland-vesicles vary according to their size.

In the supra-renal capsules which are smallest of all, and measure under 9-100ths of a line, there are no gland-vesicles to be seen, but only nuclei: to these we shall immediately return. But in supra-renal capsules which are somewhat larger, the nuclei are partly included in cells.

By a yet further enlargement of these organs, the gland-vesicles also appear: they contain fine molecules, fatty granules, and nuclei. These are vesicular, flat, of circular or irregular form, and vary in size from 22 to 30-10,000ths of a line. Each of these nuclei contains a single or double nucleolus. Not unfrequently forms appear which may be connected with a division of the nucleus, where it appears cut through the middle, or even incompletely broken up into three parts.

Finally, the gland-vesicles also contain cells. By enlarging, these cells experience a gradual transition into new gland-vesicles, which are contained within the larger ones; so that we may distinguish them into mother-vesicles and endogenous daughter-vesicles, just as often happens in other cells, to wit, those of cartilage. The endogenous vesicles occur in the older ones in variable numbers. The smaller gland-cells contain only a single nucleus; others possess two or three of them, which sometimes lie closely packed on each other. Finally, in other cells, three, four, five, and more nuclei occur; and in this manner, by an increase in the number of the enclosed nuclei, and at the same time a continual further extension of the cell membrane, the cells experience a transition into glandular vesicles.

These conditions, which were first observed by Ecker, and which I can completely confirm from an examination of the same animal, will quite permit us to conclude as follows regarding the development of the glandular vesicles. In the smallest gland-vesicles a multiplication of nuclei takes place, most probably from those already present, by the method of fission. This multiplication extends itself to free nuclei, as well as to those which are included in cells. In the latter case, the cell-membrane must be more and more extended by the formation of the nuclei; and in this manner the cells of a gland-vesicle themselves are changed into new endogenous vesicles. By this process, the mother vesicle itself is considerably extended; so that, finally, its membrane comes into contact with the sheath of the supra-renal capsule. Finally, after the membrane of the mother vesicle is destroyed new areolar tissue seems to be developed between the secondary vesicles. In this way the small supra-renal capsules of the Pike experience their growth.

In large old Pikes, the process of multiplication and growth seems no longer to occur. In their supra-renal capsules, the fibrous foundation is more considerable in quantity, so that by its means the gland-vesicles are more separated from each other.

So also in the genus Cyprinus, where a precisely similar structure of the supra-renal capsules may be observed, one lights upon conditions of nuclei in the gland-vesicles which suffice to prove the transition of gland-cells into gland-vesicles. As to the problematical organs of the Myxine and Petromyzon, the glands which Müller discovered in the Myxinoid fishes consist of tufts of small elongated lobules, which are clothed with a kind of cylindrical epithelium.* Concerning the glands in

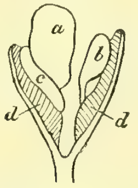
* See the drawing of this glandular structure in J. Müller's Essay.

the Petromyzon, Ecker only remarks, that the microscopic constituents do not afford any foundation for the view that they are supra-renal capsules.

III. *Development.* — The supra-renal capsules begin at a very early date of fœtal life. In the human subject they appear simultaneously with the kidneys in the seventh week. The mode of their commencement is not yet understood with certainty. Nevertheless there is scarcely any doubt that the statement of Arnold, according to which the supra-renal capsules are formed by a projection of the Wolffian bodies, is erroneous. Most embryologists, as Valentin *, Bischoff †, and others, find that another method of beginning obtains, namely, that these organs are developed from an independent blastema, which certainly lies very close to the Wolffian bodies, but has nothing at all to do with them. According to Meckel's observations, both supra-renal capsules constitute at first only a single mass; and Valentin's researches on the embryo of the Dog and Sheep harmonise with this statement. But, nevertheless, this opinion may be founded on an error. Müller found that the supra-renal capsules of a large human fœtus at the eighth week were plainly double, only they lay very closely together at their inferior part. Bischoff's extensive researches on the embryo of Man and other Mammalia, confirm this statement of Müller, and explain the error of Valentin and Meckel. The embryonal form of the supra-renal capsules in man is distinguished from the later condition by its being composed of large lobes; and thus, to a great extent, it resembles its permanent condition in some animals.

It is highly singular that the human supra-renal capsule in the earlier period of fœtal life, is not only much larger in proportion to the size of the body than it is at a later stage, but that it also considerably exceeds the kidney in size (*fig.* 543.). This is shown by

Fig. 543.



From an embryo of 8 *lines in length.*
a, Supra-renal capsule; *b*, Kidney; *c*, Sexual gland; *d*, Wolffian bodies.

numerous observations of Meckel, Müller, and others. In a human embryo of the ninth week, Ecker has recently made the same observation. In the embryo of the tenth to the twelfth week, which measures about two inches in length, the kidneys and supra-renal capsules are for the first time of pretty equal size. While, on the other hand, in the sixth month the kidneys are, as was found by Meckel, already about double the size of the supra-renal capsules, and their weight is to that of these latter as five to two. And as this comparative diminution of the supra-renal capsules proceeds further, the proportions by weight are in the mature embryo as three to one. And even beyond this time, they experience a continual diminution, so that finally, in the adult, the supra-renal capsule is only 1-28th the size of the kidney.

Strange to say, this extraordinary size of these organs during the fœtal period, does not obtain in the other Mammalia. In the earliest period of their embryonal life, the kidneys have always been found considerably larger than the supra-renal capsules. In them both organs appear to grow in precisely equal proportion to each other, so that their (comparative) weight remains the same in the adult animal as in the fœtus. According to Ecker, the supra-renal glands of the new-born kitten are 1-56th to 1-60th the size of the urinary glands. So also the other classes of Vertebrata seem to accord with the Mammalia in this respect. At least Ecker observed, in the embryo and adult animal of the Coluber natrix, the same relative proportion of size between the kidney and supra-renal capsule.

If we regard the situation of the supra-renal capsules in the animal kingdom, we shall find a different condition in the different classes.

It is well known that the Wolffian bodies begin in the embryo at a very early period, and that these, from their structure and function, must be regarded as the kidneys of the embryo; so that the name of "primordial or original kidneys," may be applied to them with all accuracy. Now these primordial kidneys have a very different duration in the different classes of Vertebrata. In Fishes they remain as the urinary glands during the whole of life; since in them, as Baer and Rathke found, an organ similar to the kidneys of the higher Vertebrata is never developed.

The kidneys of Fishes are, therefore, primordial kidneys.

But in the three higher classes of Vertebrata the fact is found to be otherwise. Here the primordial kidneys pertain to only a part of the fœtal life, and then make way for the true kidneys, which are situated beneath the supra-renal capsules.

Therefore, the supra-renal capsules of fishes are placed on the Wolffian bodies, while in the other Vertebrata they are in connection with the kidneys.

In Man, in whom the supra-renal capsules are at first uncommonly large, the primordial kidneys disappear remarkably early, so that in the second month they have vanished even to the smallest relics.

The development of the tissues of these organs is as yet most incompletely known; at present we have only a single statement of Ecker's respecting it. In a human embryo of twelve weeks, this anatomist found a very

* Handbuch der Entwicklungsgeschichte des Menschen, Berlin, 1835.

† Entwicklungsgeschichte der Säugethiere und des Menschen, 1842, S. 291.

distinct cortical and medullary substance. But only part of the morphological constituents were present; viz., the elementary granules, fat, and nuclear structures. Cells, with or without a membrane, were only sparingly found; and gland-vesicles were altogether absent. The embryos of other Mammalia exhibited the same results. In the fœtus of an ox of 1½ feet in length, the vesicles were for the first time detected; and in this instance, as in those of the mature animals previously described, the gland-vesicles were, according to Ecker's opinion, developed from enlarged cells.

In any case it is exceedingly interesting to observe, that in spite of the very early foundation of the supra-renal capsule, this organ seems to rest for a considerable time; since, before their gland-vesicles are developed, we cannot ascribe any activity to the supra-renal capsules. But in man, these vesicles are only developed when the period at which the supra-renal capsules attain their greatest bulk is long passed.

IV. *Physiology.* — Finally we apply ourselves to the functional relations of the supra-renal capsules. Unfortunately, as regards the activity of the glands of blood-vessels, they all veil themselves in an impenetrable obscurity. The recent vast strides of Physiology have passed over them without leaving any traces; the last ten years having only brought some new hypotheses concerning the function of these organs, and very doubtfully enriched the already great number of older conjectures.

It is not the aim of this essay either to answer or to enumerate all that physicians of earlier and later times have imagined as the possible function of the supra-renal capsules. These conjectures, for the most part ephemeral, may be properly left to the history of anatomico-physiological science; and since we willingly disclaim the intention to come forward with a new hypothesis, we will only call attention to some points of this mass of matter.

Now that the minute structure of the supra-renal capsules is known, it becomes even more important to dissent from the opinion of Cuvier. He attributed to the supra-renal capsules pretty much the same function as the kidneys, "because these two organs have much similarity with each other, both in their form, and in the tissues of which they are composed." At present we know how great is the diversity between the tissues of the two organs. Besides, the want of an excretory duct is another fact completely passed over by Cuvier. The opinion of Meckel, that the supra-renal capsules stand in dependance with the sexual functions, rests on just as little foundation, and has been already confuted at length by Nagel in his work. So also the conjecture of Bergmann* and others — according to which the supra-renal capsules stand in a very close relation to the nervous system of the fœtus — is equally erroneous. We will willingly admit the correctness of the observation, that in brainless monsters the supra-renal capsules are generally deficient; but we are forced to add, that we cannot annex any distinct notions to this close relation to the nervous system. Besides, this would suppose that the function of the supra-renal capsule differed in the fœtus and in the adult animal; since certainly no one would seriously defend such a relation of their function in the latter case. And the support which this view seems to receive from the structure of the supra-renal capsules, is likewise only a fallacious one. At one time, attention was drawn to the great richness of the supra-renal capsules in nerves, without reflecting that this is the case in only one out of the four classes of vertebrate animals: and in the same way, the superficial likeness possessed by the gland-cells and ganglion corpuscles was adduced in order to make out the supra-renal capsule as a kind of ganglion. This hypothesis was put aside by the discovery of the gland-vesicles. And especially we would briefly remark, that all those theories which ascribe to the supra-renal capsules a special import during embryonal life, have originated from contemplating them in the human fœtus, in whom they are exceedingly large. Had the supra-renal capsules of other animals been kept in view, those opinions could scarcely have been taken up; and the special size of these organs in the human embryo would have been recognised for that which it really is, an anomalous, isolated condition, which possibly stands in a causal relation with the swift disappearance of the Wolffian bodies. And, as we have already remarked, even apart from this, the absence of the gland-vesicles from the supra-renal capsules of the small embryo is a fact which must not pass unnoticed.

We will, therefore, only attempt to answer such physiological questions concerning the supra-renal capsules which are possibly susceptible of solution, and defer their full understanding to the future.

We will see whether the supra-renal capsules in general can be called glands, and how far they correspond with the other glands of blood-vessels, with the thyroid, thymus, and spleen. And then we may answer the question, "whether the supra-renal capsules generally eliminate a glandular secretion, and whether this secretion is to be regarded as similar or diverse in the whole of the vascular glands?"

Microscopic anatomy has taught us to recognise three kinds of form under which glands are developed in the higher animals. The first is a fine tube or canal of different length; the second is a small globular or elongated sac, which is open at one end; and the third form is that of a globular and completely closed vesicle. A very delicate structureless membrane, the membrana propria, forms the frame-work of all these glands; and it is distinguished by its insolubility in dilute alkalies. On its exterior, it is surrounded by

* Bergmann, Dissertatio de glandulis supra-renalibus, Gottingæ, 1839.

a network of capillaries, while it includes within its interior, glandular contents in very diverse forms. These contents consist, in general, of elementary granules, of an albuminous material, of fatty granules and small drops of fat, and of nuclei and cells in the most variable quantities. Cells, which are the highest development of glandular contents, are not always found: more frequently only nuclei are noticed. It will be recollected that in speaking of the contents of the supra-renal capsules, we have stated that the development of cells occurs by the method of circumposition of a globular membrane, and the same method obtains in a number of the glands.

The first two of the three forms of glands frequently occur isolated, and thus exhibit microscopic glandules of the greatest simplicity; as for instance the stomach glands of Mammalia, the glands of Lieberkuhn, the cutaneous glands of the Frog. In other instances, glandular tubes or sacs are connected to each other in very variable number, and thus form the larger glands. In this way the kidneys and testicles originate from tubes; while from sacculi are formed the multitude of clustered glands, as those of Brunner, the salivary glands, and the pancreas.

The first two forms of glandular structure have no further interest as regards our present object; but the case is very different with respect to the third or vesicular form.

The gland-vesicles have a very diverse size, ranging from microscopic dimensions to a quarter, a half, or even a whole line or more. Their shape is always spherical, so that their membrana propria encloses a globular cavity, which contains, suspended in a fluid, all the different constituents of gland-contents previously spoken of. In very numerous experiments I have never found vesicles of this kind further divided by ensheathing membranes.

Generally the united gland-vesicles are inlaid in the fibrous tissue of the particular mucous membrane of the body; they are sometimes in greater, sometimes in smaller quantity, so that great differences, both individual and generic, may be noticed in this respect. In many places they occur with greater frequency, so as to constitute the rule, and have therefore received a special name. For instance, the glandulæ solitariæ of the intestine, and the lenticular glands of the mucous membrane of the stomach, belong to this category; while in other cases more than one or even many vesicles of this kind are grouped together to form a glandular body of some extent. Amongst such aggregations may here be enumerated the Peyerian vesicles, which form a single layer of this kind in the mucous membrane of the intestine. We find the same grouping in the ovary, where these vesicles are called "Graafian," in honour of their discoverer. But here they are somewhat more widely separated from each other by the thickness of a solid fibrous basis, or by the so-called stroma; and they enclose, beside the usual glandular contents, a peculiar body, the primitive egg or ovum.

The physiological relations of the gland-vesicles, and especially their duration and origin, are as yet little known. The facts may probably be stated as follows. The gland-vesicles arise from cells which enlarge, so that the cell-membrane becomes the wall of the vesicle, and its contents form those of the vesicle also. At least I have observed exactly this occurrence to take place in formation of vesicles in a fish of very low development which inhabits our brook (Ammocœtes branchialis). In this fish a number of glands of this kind may be found at the dilated part of the intestinal canal, on both sides of it near the spiral fold: these remain tolerably small, although they experience considerable variations of diameter. They are densely filled with large, pale, smooth nuclei, of oval or roundish form, the number of which is greater or smaller according to the size of the vesicle. Beside these are seen in the tissue of the wall of the intestine separate cells, which enclose two nuclei in no way distinguishable from those of the gland-vesicles. From these cells they pass, by all intermediate gradations, to the large vesicles. If one may generalise on this observation, it may be stated therefrom, in accordance with the proposition mentioned above, that the shut gland-vesicles proceed from cells. The gland-vesicles in the mucous membranes of the Mammalia are very unfavourable objects for examination; so that, unfortunately, in spite of many attempts, I have not been so lucky as to observe their development. So also I am unable to state in what way the multiplication of nuclei takes place, whether by a fission of the nuclei already present, or whether new nuclei arise independently of the old ones in the fluid of the gland. But I conjecture that the latter is the case.

By their further increase of size, the gland-vesicles come to lie more on the surface of the substance in which they are imbedded. But the membrana propria does not possess an unlimited extensibility, so that a period arrives when it can no longer withstand the contents, and is burst by them. This rending occurs at the place of least resistance, namely, at the upper and most external part, and engages not only the membrana propria of the gland-vesicle, but also the thin layer of fibrous tissue present superficially to this. By the occurrence of this so-called dehiscence of the gland-vesicles, its fluid contents become effused amongst the other constituents. This process has long been known to occur in the Graafian follicle of the ovary; but it may also be seen with the greatest distinctness in the vesicles of the mucous membranes, as well in the separate as in the Peyerian glands. The burst gland-vesicle is thus brought into connection with the outer world, and now resembles a wide-bellied and short-necked flask: it has thus suddenly become converted into a small sac, such as we have already found as a constituent of the glands treated of as belonging to the second variety.

After their dehiscence, the gland-vesicles appear to behave differently. Part of them by bursting arrive at the end of their career. They do not become distended with secretion a second time, but the gland-vesicles cease to exist as such in consequence of further metamorphosis. The ovary, the vesicles of which disappear by the formation of a corpus luteum, affords a proof of the occurrence of this process. While, on the contrary, other gland-vesicles seem to close again, and to become distended with new secretion, in order to their going through the process for a second or perhaps a third time. It is exceedingly difficult to come at the truth respecting this matter, but an examination of the Peyerian glands may afford us some help in the investigation.

Each Peyerian patch consists of but a single layer of gland-vesicles, which in the adult appear all to be at pretty much the same stage of development. No second row of undeveloped vesicles is ever found beneath this layer, such as might be supposed to serve as a compensation for those which have burst; so that a Peyerian patch of glands, after all the vesicles had burst, would necessarily disappear, if no closure of the vesicles followed, unless indeed a power existed to develop a new group of vesicles at some other point. Now although the Peyerian glands of Man and Mammalia certainly show individual varieties in number and extent, yet these appear too small to prove a destruction of the Peyerian vesicles after the manner of the Graafian follicles of the ovary. Besides this, I have never been able to remark the least appearance which could lead me to imagine a new development of the glandular patches. Moreover, it is a well ascertained fact, that in many Mammalia certain Peyerian gland-patches show a constant position and size at all periods. To this category belongs a very large Peyerian patch which exists in the rabbit at the point where the ileum opens into the large intestine. Such structures will scarce admit of any other conclusion than that the gland-vesicles reclose themselves after their dehiscence.

From these observations, which in part depend on researches not yet published, we shall be able to come to a decision respecting the glandular nature of the supra-renal capsules.

In them the same gland-cells appear; the same membrana propria, capable of withstanding alkalies. Exteriorly this is surrounded by capillaries, and interiorly it contains the same mass, consisting of molecules of a protein substance, fatty granules, nuclei, and cells developed by circumposition of a membrane. We also find a development of gland-vesicles from cells identical with that which was met with in the Ammocœtes. The multiplication of the nuclei here occurs by the method of fission. And since, in the supra-renal capsules, these undeveloped gland-vesicles occur in predominant quantity, we may, therefore, well imagine that the old gland-vesicles are destroyed in these organs, in which they undergo dehiscence. But their contents are not extruded outwardly, as are those of the gland-vesicles previously described, but into the fibrous framework of the organ, in which they exist in the fluid form, and from which they are subsequently received into the vascular system either by immediate or mediate resorption.

We are therefore correct in regarding the supra-renal capsules as glandular organs, and their function as secretory; and any hypothesis which ascribes to them a function other than secretory, may be safely considered erroneous.

If we now address ourselves to a comparison of the structure of the supra-renal capsules with that of other vascular glands, we shall see how great a resemblance obtains.

Unfortunately, we do not possess such experimental researches regarding all of them as those which Ecker has published in his work on the supra-renal capsules. Only the thymus gland has found an accurate observer in Simon.* Nevertheless, we already know thus much, that in two of the three other vascular glands, viz., in the thymus and thyroid glands, a similar structure obtains. Bardeleben † was the first to observe what Ecker ‡, Gerlach §, Schaffner ‖, and others confirmed, that in the thyroid gland gland-vesicles occur grouped in masses, imbedded in a loose cellular tissue, and surrounded by blood-vessels. In Man, they are seen with some difficulty; but are more easily made out in most of the Mammalia, and best in Birds and Reptilia. These vesicles, which attain a size varying from 6-1000ths to 5-100ths of a line, begin as cells which measure 5 to 10-1000ths of a line, and which are connected with them by all the transitional forms. Suspended in a fluid which occupies their interior, are varying numbers of elementary granules of an albuminous material; and besides these, fatty granules, nuclei of 2 to 3000ths of a line, and finally, cells with one or more nuclei. In the earlier periods of fœtal life the vesicles are not to be met with; but their place is entirely occupied by cells, — a condition exactly similar to that which was met with in examining the supra-renal capsules.

So also the gland-vesicles of the thyroid appear after some time to be destroyed, and their contents resorbed. This is shown by the fact, that frequently only younger and undeveloped forms of these are to be met with in the adult animal; while in other instances, the fully developed vesicles occur in excessive numbers. Some distinction between the thyroid and supra-renal capsules, although not an important one, may possibly be deduced from the fact, that in most of the Mammalia, the nuclei and cells are ranged as an epithelial stratum on the inner surface of the vesicles, so that the remainder of their cavity

* A Physiological Essay on the Thymus Gland, London, 1845.

† Observationes de glandularum ductu excretorio carentium structura, Berolini, 1841.

‡ Loc. cit.

§ Loc. cit.

‖ Henle und Pfeuffer's Zeitschrift für rationelle Medizin, 1849.

is filled with a more or less clear fluid. Nevertheless, in Man, the gland-vesicles are generally completely filled with the morphological constituents of their contents.

As regards the thymus, we have lately had Simon's researches extended by Ecker, Gerlach, and Schaffner. The gland-vesicles here likewise enclose similar contents. The quantity of the elementary granules seems to be very variable, and nuclei form the greater part of the contents. In general, cells occur but very sparingly. According to Simon, their number is increased by involution of the organ, in which case, also, fat molecules are wont to appear in place of the elementary granules. As to the gland-vesicles, they deviate from those of the vascular glands hitherto described. In the embryo of the Adder and of Birds, Ecker saw many completely shut gland-vesicles, which everywhere passed into sacculi by pouchings of their membrana propria. In the human thymus, and that of Mammalia generally, only a few vesicles of this kind were found, and the tunics of these exhibited the same condition. Thus the thymus gland exhibits a similarity with the clustered glands; but is distinguished from these by the want of an excretory duct. And these differences of the gland-vesicles, together with the great number of the nuclear structures, somewhat distinguish the thymus from the supra-renal and thyroid glands.

The structure of the spleen is even more different, — if it be allowable to decide upon this organ, which is so uncommonly difficult of examination, from a few observations of a somewhat contradictory tendency. It is only the well-known Malpighian corpuscles which can be regarded as glandular structures. In fact, this opinion would seem to be correct, since Ecker found a delicate membrane enclosing the vesicles. Nevertheless, lately, an opinion has been put forth on many sides, and based on continuous research, that the Malpighian corpuscles are not closed vesicles, but stand in connection with the lymphatics, so as to constitute only vesicular dilatations of these vessels. This view, which is maintained by Gerlach and Schaffner, is especially corroborated by the fact, that the contents of the splenic vesicles differ from those of the other vascular glands, and closely approximate to those of the lymphatic vessels. Thus we remark in their contents, cell nuclei in very predominant quantity, the diameter of which amounts to 2-1000ths of a line. These nuclei appear sometimes smooth, sometimes granular; they often exhibit one or two nucleoli, while in other instances they have none. Roundish cells of 4 to 5-1000ths of a line, and closely surrounding a nucleus, may also be remarked in sparing quantities. The above-mentioned relation of the Malpighian corpuscles to the lymphatic vessels is probably supported by another circumstance. Another cell formation may be found in almost every spleen, and certainly in the splenic vesicles also. They are large, globular cells, measuring from 5 to 10-1000ths of a line, and with contents of a very different kind; so that from this fact one might conjecture that they form a number of very different structures, which, however, are connected with each other by transitional forms. Thus a part of these cells contain more or less dark elementary granules; another part enclose larger yellowish, or yellowish brown and tuberculated corpuscles; while finally, other cells contain, with the latter corpuscles, one or many completely developed blood corpuscles. This group of cells is susceptible of a double interpretation. In the first place, effused blood corpuscles may be enclosed by a cell membrane, and may be broken up into elementary granules in its interior. This view has been taken by Kölliker*, and is supported by pathological appearances. But the process may be exactly the reverse; the blood corpuscles may be developed in the interior of the cells, and then, after the bursting of the cell wall, become free. And should this latter view, which is especially maintained by Gerlach†, ultimately turn out to be correct, then we shall have in the Malpighian vesicles of the spleen a new development of blood corpuscles, just such as occurs after another scheme, in the other district of the lymph and chyle system. So that the spleen would be an organ especially serving for the development of blood corpuscles, and the old explanation set forth by Hewson would be the correct one. But if the process be that which Kölliker supposes, the spleen will exercise the function of destroying the blood corpuscles. In any case, it is worthy of notice, that no such cells containing blood corpuscles occur in the other vascular glands. Gerlach could not discover them in the thymus gland, and they would scarcely have escaped Ecker's careful observations of the supra-renal capsules. So likewise, in a number of examinations of supra-renal capsules, it is impossible to find the least trace of their presence. Therefore by all this the spleen is greatly distinguished from the other vascular glands. Such great differences of structure and contents will not allow us to attribute a like function and a like secretion to all these organs. Certainly we cannot at all state of what kind these differences of secretion are, since the materials prepared by these vascular glands are, as far as regards their composition, completely neglected: but that such differences must exist, I think microscopic research will quite warrant us in saying. In this respect the thyroid gland and supra-renal capsule agree most nearly together, since in general terms, there is a great correspondence in their structure. And, as the spleen is the widest separated from them, so it is not unlikely that future research may remove it from amongst the vascular glands.

Since the chemical constitution of the secretion is unknown to us, we are unable to

* Vide Landis's Dissertation, apparently under Kölliker's direction, Beitrage zur Lehre über die Verrichtungen der Milz, Zürich, 1847. See also the article SPLEEN.

† Loc. cit.

state either the object of the vascular glands in general, or that of the supra-renal capsules in particular. Pathological study also has, up to the present time, failed to afford anything which would allow any safe conclusion to be drawn concerning the function of the supra-renal capsules. By their concealed situation, they elude the experiments of the physiologist; besides this, they are so small, that their secretion can scarcely have any very sudden and visible influence on the vegetative life of the body. So that even by such an eager operative interference as the extirpation of this gland, the wished-for result might scarcely be obtained.

I therefore repeat, that at present we are completely in the dark as to the function of the supra-renal capsules; we know not at all in what way they operate, and on this account all references of the supra-renal capsules to this or that organ — such as have so often been made — are altogether empty and worthless. We may see at a glance that it would be just as correct to assign a relation of the supra-renal capsules to the eye or ear, as to the sexual or urinary organs.

Ecker, who, in opposition to our view, regards the secretion of all the vascular glands as one and the same, keeps its contents of fat and protein compound especially in view, and conjectures that all the vascular glands are adapted to the formation from the blood of a secretion which is rich in protein and fat, and which being subsequently retaken into the current of the blood, in this manner benefits nutrition. But apart from the fact, that one cannot see why such a fluid should take this round-about way through the vascular glands; apart from this, the quantity of protein compounds in the secretion of all the vascular glands of the body, even if we take this at the highest estimate, is far too small to render any enrichment of albuminous materials which the body could obtain in this way other than a very inconsiderable one. The want of an excretory duct affords certainly this information, that the secretion prepared by the vesicles of the vascular glands is again received into the blood; but even this notion has connected with it much that is obscure and uncertain.

The difference of the function of the vascular glands is yet further upheld by the circumstance that their vital duration and activity is different. The function of the thymus is the first to wane; that of the supra-renal capsules seems likewise much diminished in more advanced age; while, on the contrary, the activity of the spleen endures for the whole life. These organs experience an excessive deposit of fat in their vesicles, and by this means gradually disappear.

(*Heinrich Frey.*)*

SWEAT. — The cutaneous secretion is formed by the spiral sudoriferous canals discovered by Breschet and Purkinge. In considering this subject it is important to make the distinction between sweat and that exhalation which is constantly, and at the same time insensibly, excreting from the healthy skin. The latter is the manifestation of a function indispensably necessary for the continuance of life; while sweat may be regarded merely as an occasional result, and as producing on the surface certain excretive products which under ordinary conditions only appear in small proportion on the skin, and find their more natural exit from the organism through other channels. It is true that sweat contains among its constituents the ordinary products of the insensible perspiration, but it also contains other matters of a solid kind which do not appear in a fluid form unless cutaneous excitement be brought about, and which in cold weather and in the case of indolent, inactive persons, adhere to the cuticle, and are gradually rubbed or washed off. These solid matters are not volatile at the ordinary temperature of the skin, and therefore will not pass off from the body in material quantity by any amount of perspiration. They become constituents of sweat, however, inasmuch as they dissolve in the water which, under exercise or owing to excessive temperature, appears on the surface. Thus sweat is constituted of the ordinary aqueous products of the natural perspiration, which appearing in large quantity ceases to be vaporised, and in addition it contains those cutaneous secretions which the water dissolves, but which, when an animal does not sweat, appear in less quantity, and adhere undissolved to the surface. As the ordinary cutaneous transpiration forms an important part of sweat, I shall proceed to consider it before entering on the more immediate subject of the present article.

In the healthy human subject, a portion of water is constantly finding its way to the surface, and under ordinary conditions is vaporised nearly as fast as it is secreted. Some difference is observed in individuals in this respect, however, so that we observe some whose skins are constantly moist, while others, though in perfect health, have the skin almost always dry, yet doubtless performing its ordinary function. Perhaps the most agreeable proportion of perspiration, and that which we should regard as approaching more nearly to the normal quantity, is that which maintains a certain moisture on the surface sufficient to impart an agreeable softness to the touch, and scarcely to convey the idea of moisture. Many attempts have been made to determine the quantity of the cutaneous transpiration, and perhaps nothing has ever been attempted so unpromising in result. It is almost certain, indeed, that we do not transpire equally during any two minutes of the day, and on no two days alike.

Sanctorius, the Venetian physician, whose aphorisms contain much valuable matter, too much neglected by the physiologists of the present day, made lengthened experiments on perspiration. The insensible perspiration has,

* The Editor begs to make his acknowledgments to his friend Dr. Brinton for this translation from the German MS. of Professor Frey.

indeed, been termed "Sanctorian" in honour of him.

This subject, curiously enough, received some attention from the merry monarch Charles the Second, who instituted many experiments on the subject. Among other less exalted, but probably more trustworthy observers, may be mentioned Dodart, Keil, Robinson, Home, and Linings, and of later date Lavoisier and Seguin. According to an experiment of Home, the perspiration during the twelve hours of night varies from 12 to 18 oz., and in $23\frac{1}{2}$ hours the discharge amounted to 3 lbs. $3\frac{1}{2}$ oz. On another occasion, however, the amount was only 2 lbs. $6\frac{1}{2}$ oz. Keil states the medium quantity of perspiration to be 31 oz. only. Robinson states the amount for summer to be 27 oz., and in winter 30 oz. daily. Hartmann, in Germany, makes the daily amount of perspiration 45 to 46 oz. Dodart, in France, gives 40 oz. 3 dr. 26 gr. for summer, and 26 oz. 46 gr. for winter. Sanctorius found that in the warm humid air of Venice, having taken 8 lbs. of ingesta, the perspiration in the 24 hours amounted to 5 lbs., the fæces to 4 oz., and the urine to 69 oz.

The observations made by Linings, in the climate of South Carolina, bear importantly on this subject. He found that while perspiration, as might be expected, was most abundant in the warm weather of summer, the urine diminished proportionally, and that the converse pertained for the winter. He observed the perspiration to exceed the urine during seven months, and the urine the perspiration during five months of the twelve. The largest proportion of urine observed was 143 oz., which occurred in December. The largest proportion of perspiration was 130 oz., and was observed in September. The ingesta were to the perspiration as 2·18 to 1. The perspiration of the whole year was to the urine as 1 to 1·08. These experiments differ from those of Sanctorius and Rye, in showing that the urine exceeds the perspiration even in a hot climate.

On reviewing all that has been done by various experimenters, it appears doubtful whether, even in warm climates, the cutaneous exhalation exceeds that of the urine, and we ought most probably to regard it as considerably below the quantity stated by Sanctorius. It must be remembered that, as in the experiments described above, the perspiration is estimated from the loss sustained by the body during a given period, after subtracting the weight of fæces and urine discharged; we have the pulmonary exhalation therefore included in the account, as well as the cutaneous.

Mr. Cruikshank made experiments which are free from this source of error. He placed his hand in a glass jar, making it air-tight by means of bladder fixed round his wrist and also bound tight to the mouth of the jar. He assumed that his hand presented a surface $\frac{1}{60}$th that of the whole surface of the body, and from that datum arrived at the conclusion that the exhalation from the skin was 7 lbs. 6 oz. in the 24 hours, which, under exercise, would amount to 12 lbs.

Mr. Abernethy made an experiment very similar to the above, but according to his calculation, the exhalation for 24 hours would amount only to $2\frac{1}{2}$ lbs. This extraordinary difference may perhaps be accounted for by the fact that Mr. Abernethy continued his experiment six hours, and Mr. Cruikshank only one hour, and such being the case, the exhalation may have nearly ceased some length of time before six hours had elapsed, owing to the extremely moist atmosphere in which Mr. A.'s hand was placed. Cruikshank, it will be seen, would have to multiply by 24, and Abernethy by 4 only for the result of 24 hours. Thus the former would magnify the excess (obtained by the first hour affording a dryer atmosphere) into an important quantity.

Lavoisier and Seguin have made excellent experiments with a view of ascertaining the amount of cutaneous exhalation. They enclosed the whole body in a varnished silk bag. There was a small opening to this, which was carefully cemented around the mouth of the subject of experiment. Thus all the moisture from the lungs escaped, while the cutaneous exhalation was confined in the bag. By weighing the body before and after leaving the bag, the total loss from skin and lungs was ascertained. The amount of loss by the lungs was ascertained by weighing the person before he got into the bag and immediately before he left it. After a long series of experiments conducted in this manner, Lavoisier and Seguin found that the mean loss by pulmonary and cutaneous exhalation amounted to 18 grs. per minute, or 2 lbs. 13 oz. in 24 hours. Of this the pulmonary discharge was 15 oz., and the cutaneous exhalation 1 lb. 14 oz. This they regard, then, as the mean amount of daily perspiration. The greatest quantity of matter perspired in a minute, was 26·25 grs. troy, and the minimum 9 grs. Exhalation is increased by fluids, but not by solid food. It is at its minimum during meals, and at its maximum during digestion.

Under certain conditions vapour has been observed to escape from the body in very great quantity. Thus, Haller observed, when in the subterraneous caverns of Clausthal and Rammelsberg, that a distinct cloud or smoke could be perceived rising from the naked human figure.

Some diversity of opinion has prevailed among experimenters as to the gases which pass off from the body in company with the water, by the function of insensible perspiration. Abernethy and Mackensie detected carbonic acid, and Collard de Martigny found nitrogen in addition. These gases appear in variable quantity, and are sometimes altogether absent. After muscular exertion, and after meals, they appear in great abundance. According to Trousset, Barruel, and Ingenhouss, nitrogen is sometimes exhaled without carbonic acid. Monsieur Collard found that the cutaneous transpiration contained most nitrogen when an animal diet had been used, while carbonic acid prevailed when vegetable food was taken. This experimenter also satisfied himself that carbonic acid was evolved from the skin in a gaseous form, and need not be the result of oxydation of carbon by contact with air, as he was able to collect it over water from the skin. The insensible cutaneous transpiration may be regarded then as composed of aqueous vapour, carbonic acid, and nitrogen gases; the two latter not only varying in proportion like the first, but probably being sometimes absent, even in health, according to conditions of the organism, which are not yet sufficiently investigated in relation to this subject.

When, under the conditions referred to at the commencement of this article, the surface becomes covered with sweat, the various matters passing away from the skin by excessive secretion have been examined by chemists with the following results: —

The total solid matters passing away from the unexcited skin have been calculated at about 7 to 8 scruples in the 24 hours, but the very nature of the inquiry prevents any great reliance being placed in such results.

When sweat is collected, as was done by Simon, from persons subjected to the vapour bath, it appears as a turbid fluid, yielding a deposit by standing. This deposit consists of epithelium scales. The clear fluid was found by Simon to possess a specific gravity of 1003 to 1004. This result, however, must be modified continually by the water condensed on the surface from the aqueous vapour of the bath. The fluid was acid, but only very slightly so, and in the course of twenty-four hours it became neutral. The acidity of the sweat was therefore dependent on the presence of carbonic acid. Ammonia was evolved from it after exposure. Simon analysed his own sweat. He found it to develop an odour of ammonia, and could detect that gas by testing with the vapour of hydrochloric acid. On evaporation, the peculiar smell of animal extractive matter was observed. When the dry matter was triturated with potash, ammonia came off. Sulphuric acid added to another portion developed sulphurous acid at first, and afterwards produced a strong odour of acetic acid. In one instance observed by Simon, the sweat gave off the odour of butyric acid so strongly as to leave no doubt on his mind of the presence of that substance. From various experiments, Simon concludes normal sweat to contain —

1. Matters soluble in ether: traces of fat, sometimes including butyric acid.

2. Matters soluble in alcohol: alcoholic extractive, free lactic or acetic acid, chloride of sodium, lactates and acetates of potash and soda, lactate or hydrochlorate of ammonia.

3. Matter soluble in water: aqueous extractive, phosphate of soda, and, occasionally, alkaline sulphate.

4. Matters insoluble in water: desquamated epithelium, phosphate of lime, and peroxide of iron.

Berzelius examined and analysed sweat as obtained from the forehead. He found it to contain much the same substances that exist in the acid juice of flesh. He states chloride of sodium to be in excess, however. The skin is certainly an active excreter of free phosphoric and lactic acids, and assists the urine in its important office of discharging these acids from the system. Landerer has lately shown the presence of urea in healthy sweat, and it is probably by decomposition of this substance that collected sweat becomes ammoniacal. Thus, the skin would appear, under varying conditions, to assume the excretory duties of the lungs and kidneys, and we are almost constrained to regard its function as supplementary as well as complimentary to that of respiration and the excretion of urine.

Anselmino has, perhaps, made the best analyses of the sweat. According to him one hundred parts of the solid matters of sweat contain —

1. Substances insoluble in water and alcohol (chiefly calcareous salts)	2·0
2. Aqueous extractive matter (regarded as salivary matter by Anselmino, according to Berzelius without sufficient reason), and sulphates - - - -	21·0
3. Spirituous extractive (chloride of sodium and osmazome) - -	48·0
4. Alcoholic extractive (osmazome, lactic acid and its salts, regarded by Anselmino as acetic acid and acetates) - - - -	20·0

In order to obtain the solid matters of the sweat, Anselmino collected it in the vapour bath by means of clean sponges. The fluid so obtained was filtered, and the water distilled off. Acetate of ammonia was found in the receiver. Simon considers acetic acid to be a constant constituent of the sweat, and with Berzelius considers hydrochlorate of ammonia to be a normal component of the fluid. Simon, though agreeing in the general with the results of Anselmino, failed to detect sulphates in freshly collected sweat. He found it, however, in the incinerated residue, from which he infers that some of the constituents of sweat contain sulphur.

The following is Anselmino's analysis of sweat in 1000 parts: —

Water - - -	995·00	987·500
Epidermis and calcareous salts - -	·10	·250
Aqueous extractive matter (sulphates)	1·05	2·625
Spirituous extractive, chlorides of sodium and potassium -	2·40	6·000
Alcoholic extractive, acetates, lactates, and free acetic acid -	1·45	3·625

In the ash of the dried residue of sweat, Anselmino found carbonate, sulphate, and phosphate of soda, chloride of sodium, phosphate and carbonate of lime, with traces of iron. In every 100 parts of dry matter of sweat, he found 22·9 of these fixed saline matters.

But little is known concerning the sweat of the lower animals. Fourcroy analysed the white powder which hangs to the coat of the horse when sweat has dried upon it; he detected urea in that substance, but Anselmino could not. According to the latter chemist, the white matter is made up of the following constituents: —

1. A substance of acid reaction, with an alkaline lactate or acetate.
2. Extractive matter possessing the odour of the animal; and chloride of sodium.
3. A brown extractive matter soluble in water and precipitable by infusion of galls. Alkaline chloride and sulphate.

The ash consisted of alkaline sulphates and chlorides, but no carbonates or phosphates; phosphate of lime and magnesia, with traces of oxide of iron.

Sweat in disease. — The sweat in disease has been submitted to examination in a very unsatisfactory manner, but few analyses having been made. Dr. Piutti, of Elgersburg, made analyses of the sweat obtained from three patients who were undergoing the water cure, and obtained the following results: —

1. Patient suffering from chronic gout, sp. gravity of the sweat 1003·5.

Water	995·5
Chloride of sodium	3·0
Phosphate of ammonia	·5
Acetate of ammonia	·5
Hydrosulphate of ammonia	a trace
Extractive matters	·5
	1000·

2. Patient the subject of gout during six years, sp. gravity of the sweat 1004.

Water	993·0
Chloride of sodium	4·0
Phosphate of ammonia	0·8
Acetate of ammonia	0·6
Hydrosulphate of ammonia	a trace
Extractive matters	1·6
	1000·

3. Patient suffering from paraplegia, otherwise healthy, sp. gravity of the sweat 1003.

Water	994·6
Chloride of sodium	3·3
Phosphate of ammonia	1·1
Acetate of ammonia	0·5
Hydrosulphate of ammonia	a trace
Extractive matters	0·5
	1000·

The animal matter possessed a green colour in this case. Soluble in ether, but not in alcohol.

The perspiration in different forms of disease possesses a peculiar odour, and many very fanciful opinions have been given on this point. Scabies is said to afford a mouldy odour; jaundice is musky, and syphilis sweet. In ague, the odour of fresh-baked brown bread is said to pass from the skin. Stark states that the quantity of lactic acid is increased in the sweat in scrofula, rhachitis, and some cutaneous eruptions.

Prout noticed an increase in the quantity of salts in sweat in a case of dropsy. An excess of salts has also been noticed by Anselmino in a severe case of gout. It has been said that in cases of gouty and urinary concretions the quantity of phosphate of lime is increased. As regards the latter form of disease, there is no good reason to believe the opinion above stated to be true.

A great increase of lactic acid is observed in cases of rheumatism and gout; the sweat in such cases is always extremely acid. Anselmino, however, states, that he has observed the sweat *after* a gouty attack has passed off, containing a large proportion of ammonia. Anselmino and Stark state that they have detected albumen in sweat; the former in rheumatic fever, the latter in gastric, putrid, and hectic diseases, and in cases generally immediately before death. Simon could not detect it in sweat which he obtained from the breast of a person suffering from phthisis in the colliquative stage.

Fat is also said to be found in large quantity in colliquative sweats. Bilin and biliary colouring matter, or biliphæin, have been found in the sweat of icteric persons. Berend says he has observed it in bilious fevers.

Voigtel states, that he observed blood to sweat from under the arm of a young man after violent exertion. Such perspiration is also said to have been observed in scurvy and low typhus fever. Uric acid has been found in the sweat of gouty patients, probably in the form of urate of soda.

Landerer observed a red-coloured sweat in a fever patient's axilla, which he believes to have contained the red colouring matter of the urine (uroerythrin). Blue perspiration has been noticed by several writers. Dr. Bleifuss noticed it coming from the foot of a patient suffering from abdominal disease. Michel noticed it in hysteria and hypochondriasis. Sugar has been detected in the perspiration of persons affected with diabetes, by Nasse. Various substances used internally as medicines, as articles of diet, or taken for the purpose of experiment, have been recognised in the sweat. These are, according to Stark, sulphur, mercury, iodine, iodide of potassium, assafœtida, garlic, saffron, olive oil, rhubarb, indigo, Prussian blue, and copper.

Landerer observed, that if he took quina his sweat became bitter.

In cases of Morbus Brightii I have been able more than once to detect urea in the perspiration, and I am inclined to believe it constantly present both in cases of suppression and retention of urine.

I have stated that experiments lately made by Landerer, the Athenian chemist, have proved urea to exist in the sweat in health. If this be proved, we of course can no longer regard it as an abnormal constituent of that fluid, but must look upon it merely as present in excess in the diseases above alluded to.

(*G. Owen Rees.*)

SYMMETRY (συν—μετρον). In its general acceptation this word means a just and harmonious proportionment of parts to one another and to their whole; in anatomy, however, it has a different and more restricted meaning. With its anatomical signification alone I have now to deal, and that may be defined as follows: — Symmetry is a word used to express an idea that would be more correctly represented by a verb than a noun, for it is the idea of not a thing but a fact — the fact, namely, that one half of an animal is usually an exact reversed copy of the other — the right side is a reversed copy, or repetition, of the left. To this there are numerous exceptions, even in the human subject; of which hereafter.

That unreversed *serial* copying or repetition which is observable, for instance, between the scapular and pelvic limbs, is enunciated by the analogous expression *serial homology*. The point on which a distinction may be made between symmetry and homology, is that of the reversing of the copy or repetition as characteristic of the latter. This characteristic seems to impress one with the notion that the two halves are parts of a whole, whereas an unreversed serial recurrence of similar parts inclines one to accord a kind of separate individuality to each repetition. A clear distinction between these two styles of repetition ought undoubtedly to be firmly impressed and maintained on the mind. I have, however, for want of a convenient inflection of the word under consideration, at the risk of some confusion, been long accustomed to use the expression *lateral homology* in reference to symmetrical repetition — and in that sense I shall have to use it in this article.

Whether the word symmetry should be applied to that antero-posterior repetition which is met with in caudal vertebræ of fishes, for instance, is not yet determined by usage, and it will be sufficient for me hereafter simply to make my remarks upon the apparent existence of it. In so doing I shall use the expression *antero-posterior homology* in a sense precisely parallel to that of lateral homology.

Lateral Repetition.—That the right hand and foot, and the right side of the head and trunk, are the exact counterpart of the left is a fact so obvious, that merely to assert it seems an unnecessary truism. It should, however, by no means be regarded as a matter of course. It might have been otherwise.

The human skeleton is, normally, perfectly symmetrical in all its details, and so are the skeletons of all vertebrate animals, with the exception of the Pleuronectidæ, or flat fishes, noticed hereafter. The archetype or abstract ideal figure of an osseous vertebral segment, as that of Prof. Owen, at vol. iii. p. 824., is a symmetrical form. But it is doubtful whether any single bone in the skeleton should be regarded as primordially mesial and symmetrical — whether any ossific point is originally in the middle line. The ideal archetype of the above illustrious author contains three mesial azygos elements, viz. the hæmal and neural spines and centrum; but it has always appeared to me that each of these elements should be represented in the ideal by a pair of pieces, because each of them is occasionally represented in nature by a pair of bones: Prof. Owen, for instance, regards the two parietal bones as the neural spine of a vertebra. Though there is no difficulty in conceiving the coalescence of any number of pieces into one, and though it is easy to conceive that this coalescence may have occurred before the commencement of ossification, so that two or more of the points destined to become the centres of the ossifying process may be brought so close together as, when manifest by the earthy deposit, to appear but as one, yet it is not possible to conceive that two pieces can be developed from one ossific point. The single azygos condition may proceed from the double, but the double cannot proceed from the single; therefore the double condition must be regarded as the primordial, and should hold place in the abstract type. There are occasionally met with certain monstrosities which seem to show in a remarkable manner that a vertebra is composed of two lateral halves that are primordially separate. Thus, in double-headed monsters, wherein there are two vertebral columns above, which coalesce and form one below, the half of each of the two columns which is adjacent to the other seems to be lost at the point of coalescence, and the single column below this point seems to be composed of the right half of the one and the left half of the other of the two columns. In the skeleton of the Boa Constrictor preserved in the Hunterian Museum, there are two vertebræ that are double on the right side and single on the left, bearing two ribs on the right side and only one on the left; or rather there are two specimens of right halves of vertebræ, existing independently, which are anchylosed, the one to the vertebra in advance of it, the other to the one behind it. This anchylosis alone justifies the expression "vertebræ double on the right side;" but in neither instance is it so complete as by any means to mask the real nature of the independent half vertebra. Such facts as these, especially the existence of one half of a vertebra without the other, even seem, in contradiction to the impression stated above, to claim for each half of a vertebral segment the importance of a separate individuality, such as is accorded to each vertebral segment itself. They seem to show that a vertebra is as much a compound of two lateral parts symmetrically repeating one another, as the human spinal column is a compound of thirty-three serial repetitions of vertebræ. The fact of the lateral halves being *reversed* copies of one another, I am disposed to regard as proof of their being parts only of a whole, and as disentitling them to an individuality like that which we are accustomed to assign to unreversed serial repetitions; it may, however, be regarded as not sufficient proof of this. The value to be given to such facts depends, here as elsewhere, upon the peculiar bias of different minds, and the associations that pre-occupy them. It is not necessary in the present state of our knowledge, nay, it is not expedient, to bind the mind down to this or that view of the facts that come before it.

A remark, *en passant*, is due to the consideration that the corresponding organs and parts of organs of the two sides are not only similar in form and structure, but normally of exactly the same age. The corresponding ossific points of each side make their appearance at precisely the same time, and in all respects the original development and subsequent evolution and maturation of the embryo proceed exactly *pari passu*. The exceptions alone to this rule of symmetry will chiefly occupy our consideration.

In *Man*, except perhaps in the very early stages of his existence, exceptions are offered by the heart, great blood-vessels, lymphatics of the trunk, lungs, bowels, liver, spleen, and pancreas, with their appendages. All these parts were in all probability, in the very earliest stages of the embryo, symmetrical; most of them have been proved by actual observation to have been so; it is, however, difficult to conceive this to have been the case with the following other instances of departure from symmetry.

All decussations in the middle line are a-symmetrical. Indeed, if a fibre crosses the median line anyhow but at right angles, there is a departure from symmetry. Consequently, the decussation of the optic nerves, the decussation of fibres in the medulla oblongata, and the decussation of white fibres at the linea alba, are instances of exceptions to symmetrical repetition. One is tempted, in the last instance especially, to believe that these decussations are not in the original embryonic pattern or plan; but that they are developed subsequently, in obedience to subsequent circumstances: the knowledge of the power which circumstances, external or internal, existing at any period of an animal's life, have in modifying the directions of fibres of areolar tissue, and of affecting it in other ways, aids one in this belief.

The most remarkable of the above instances, and that in which the primordial symmetry is most widely departed from, is the *heart and the great blood-vessels* that are immediately connected with it. The heart first makes its appearance as a mass of cells posited in the middle line, which soon becomes hollow and divided into three compartments, the lower one of which receives the embryonic veins, and is therefore the auricle, whilst the upper one is the commencement of the aorta, or bulbus arteriosus. The middle cavity (the ventricle) becomes bent into a horse-shoe form, so as to bring the auricle and bulbus into apposition. From the latter proceeds a median artery, giving off six arches on each side that surround the space occupied by the digestive canal and converge towards the spine, where they are received by two symmetrical aortæ. The vein that enters the auricle is a canal or sinus, that intercommunicates between two venous trunks symmetrically placed on each side of the spine, called ductus Cuvieri, the posterior continuation of which is the cardinal (future azygos and hemi-azygos) veins; and the anterior, the jugular. One of these ductus is permanent as the superior cava. The omphalo-mesenteric vein, which empties into the auricle, is at this time situated in the middle line between and in front of the cardinal veins, and into it falls the single mesial vena cava descendens. The precise periods at which these parts are first discernible, and those at which the changes about to be described take place, will be given in the article OVUM. It is the manner of their metamorphosis alone that bears upon this present inquiry. So far all is symmetrical; now commence those changes whereby the adult impar arrangement is eventually effected. The fourth and fifth (from the heart) pairs of aortic arches (the two anterior pairs), and the *right* one of the second pair, soon disappear. The *left* one of the second pair is permanent as the arch of the aorta, and the third pair persist as the subclavian arteries. The first pair give off branches to the nascent lungs. Meantime, the lower (abdominal) parts of the aortæ have coalesced, and those parts of them which intervene between the second arch on the left side (the arch of the aorta) and the third (the left subclavian), and between the first arch of the right side (right pulmonary artery) and the third (right subclavian), disappear. Now we have, on the *left* side, the first two arches uniting behind to form the left aorta. The first gives off a branch to the lungs, and that portion of it which is beyond this pulmonic branch remains, as the ductus arteriosus, pervious till birth; whilst that portion which is nearest to the heart remains, in connection with the pulmonic branch, permanent for life as the left pulmonary artery. On the *right* side the first arch alone, the second having previously disappeared, forms the right aorta, which soon joins its fellow with which it coalesces below. The proximal part of this arch is permanent, and remains in connection with its pulmonic branch as the right pulmonary artery, whilst the part of it beyond the pulmonic branch, together with its continuation, the right aorta, down to its point of junction with its fellow, soon disappears. A septum, meanwhile, has been developed in the ventricle of the heart, dividing it into right and left ventricles, and an imperfect one in the auricle. The bulbus arteriosus also has been divided by a septum, in such a manner that the first pair of arches remains in connection with one division of it, which communicates with one of the ventricles, whilst the permanent left arch of the second pair communicates with the other division, and through it with the other ventricle. It is most probable that these septa, when first developed, extend from side to side, consequently that the systemic ventricle and aorta are at first in front of the pulmonary ventricle and artery, and that the heart subsequently undergoes a twist towards the right, carrying the systemic ventricle round behind to its permanent position on the left. In reptiles, in which a great many other of the mammalian fœtal characters are permanent, the root of the systemic is in front of that of the pulmonic artery, and there is not that twining round one another of the great arterial trunks which is met with in man. Thus, then, these, the most unsymmetrical parts of the whole body, can be proved by actual observation to have been originally perfectly symmetrical, and the manner of their attainment to their ultimate unsymmetrical form can be accurately traced.

The a-symmetry of the *lungs* is little more than a trifling difference of size between the two, dependent upon the encroachment of the heart by its displacement towards the left. And the a-symmetry of the great abdominal viscera enumerated above, and of their appendages, depends entirely upon lateral displacement and excesses of growth of one side over the other, having reference to convenience of packing. This a-symmetry, greater in mammalia than in reptiles and fishes, on account of the presence of the diaphragm, which, so to speak, thrusts the abdominal viscera downwards, necessitating lateral displacement, attains its acme in man, owing to the great lateral measurement compared with the antero-posterior distance which is so conspicuous in his figure when contrasted with that of other animals. The hepatic attachments of the falciform ligament and gastro-splenic omentum landmark the original median line of the *liver;* and that larger part of it which is to the right of the ligament and behind the omentum, is the right lateral homologue of that lesser part which is to the left of the ligament and in front of the omentum. The *gall-bladder* appears to be an unsymmetrical organ, situated to the right of the median line. I am unable to state whether or not a left gall-bladder has once existed and been suppressed, or whether it is a diverticular production of the gall-duct evolved subsequently to the first sketching of the embryo; or, lastly, whether it is originally median and subsequently displaced. The anterior wall of the *stomach* is the left lateral homologue of the posterior wall. The *spleen* is an originally median organ, situated in the originally median meso-gastrium. The *great omentum* is a pouching out of the meso-gastrium towards the left, consequently its outer surface is the left lateral homologue of its inner surface.* The *pancreas* is an originally median organ, one end of which has been displaced along with the pylorus towards the right, so that its anterior aspect is the left lateral homologue of the posterior. The *intestinal canal* can be witnessed in the embryo as a straight, uniform, mesial, and symmetrical tube, until its length having become greater than that of the region which it is destined to occupy, it is compelled to arrange itself in gyrations and loops. The posterior and anterior walls of the stomach were originally, as indicated above, its right and left halves; and as to the other parts of the alimentary tube, whatever difficulty there is in recognising the manner of their displacement in the human subject, is at once dispelled by examining their condition in the lower animals. No difficulty whatever is encountered in respect of the small intestines, for their mesentery is attached nearly in the median line; the bowels themselves, however, are continually varying their position, relative and positive, according to the manner of packing most convenient for their variable contents. Not so easy is it to understand the kind of displacement which has taken place in respect of the large intestines. The *colon* is curled back, and crosses over the small intestine from right to left, forming a loop. In the human subject, the true relation of these parts is further masked by the singular circumstance of this crossing over occurring just at the point where the meso-gastrium, after having descended as the great omental bag, is returning to the spine, and the colon, finding it there, so to speak, avails itself of it, and uses it as a mesentery; anatomists have named this borrowed portion of the meso-gastrium the transverse meso-colon. In Ruminants the colon, being exceedingly long, avails itself also of the mesentery of the small intestines, into which a *loop* of it is thrust further and further until it makes three turns; so that in tracing the colon onwards with the finger, you make three spiral turns in the mesentery, and then double and return by three spiral turns placed between the former spirals.* On the other hand, in the Carnivora, where the colon is very short, it crosses over the lower end of the ileum so near to its termination that it is evident that the next degree of shortening must result in the continuation of the small and large intestines in a straight line. This actually takes place in the Reptilia †, and then there is no longer any difficulty in recognising the original mesial and symmetrical position of the intestinal tube and its appendages, so displaced in the human subject as to make this recognition so extremely difficult.

It is by no means uncommon to meet with instances where all the unsymmetrically posited organs of the human body are placed completely *vice versâ* to their usual situations; the heart pointing towards the right; its pulmonic to the left of its systemic ventricle; the vena cava to the left of the aorta; the liver in the left, and the spleen in the right hypochondrium; and the cæcum in the left iliac fossa. Almost every anatomical museum contains an instance of this kind; and in all instances where the history of the case before death was known, the average health

* See Peritoneum.

* See Ruminantia.

† See *fig.* 491. Vol. III. Peritoneum.

and ordinarily well-developed state of the subject attested the insignificance of this transposition in respect to the well-being of the individual. Such cases are most interesting from this consideration,—that *all* the unsymmetrical organs are transposed. There is, I believe, no instance on record of one, or two, or less than the whole of the unsymmetrical organs occupying the side which is not their usual one. This prompts the belief that the side which these organs shall respectively occupy is determined by a single impulse first given to one of them.

Abnormal deviations from symmetry are of extremely frequent occurrence. The blood-vessels of the body are very rarely perfectly symmetrical. In the adult subject the two sides of the body rarely match exactly in external form. The right hand is usually larger than the left. Accidental circumstances occurring to an individual frequently disturb the symmetry, but it is by no means uncommon to meet with evidence of hereditary transmission of aberrations from symmetry. Such monstrosities as supernumerary fingers and toes are sometimes symmetrical, but just as frequently, perhaps more frequently, the monstrosity exists on one side alone.

Comparative Anatomy.—I pass on now hastily to notice such deviations from symmetry as are met with in the normal conditions of the lower animals belonging to the vertebrate sub-kingdom, and to examine the question of symmetry in the other sub-kingdoms.

In all *Mammalia* there is much the same departure from symmetry in the viscera of the chest and abdomen as is found in the human subject ; but in no other mammal is the lateral displacement so great as in man, for in all others there is a greater proportionate antero-posterior depth of chest and belly. The only other notable instances of a-symmetry known to exist in the mammalian class are the following: — In the male narwhal or sea-unicorn the left front incisor tooth attains the enormous length of eight or ten feet, while the right one is found as a rudiment that never pierces the gum. Spirals in the middle line are departures from symmetry ; consequently the spiral penis of the boar, &c. must be regarded as instances of a-symmetry ; a slight excess in length of one of the halves is sufficient to produce this spiral form. The left nostril of most of the Cetacea is constantly much larger than the right.

In *Birds* there is much the same want of symmetry in the viscera of the trunk as is met with in mammals. The right one of the second pair of embryonic aortic arches however is retained instead of the left, so that the adult *aorta* arches over the *right* bronchus. But notwithstanding this, the left ventricle is the systemic one, and presents the same excess over the right, in the thickness of its walls, as in Mammalia. Both of the ductus Cuvieri are retained and form two *superior venæ cavæ*. The *liver* is situated mesially, that is to say, its great fissure and falciform ligament are in the middle line ; but its *left* lobe is usually the larger, and in the common fowl presents a fissure which is not repeated in the right. The *œsophagus* diverges slightly towards the *right*, but the cardiac orifice of the *stomach* is to the left of the pyloric. The long loop described by the *duodenum*, and the *pancreas* which is surrounded by it, are found extending diagonally across the abdomen in front of the other bowels, their extremity resting in the left iliac fossa, but they are not fixed in this position. The *gall bladder* is situated as in Mammalia. There being no great omentum, the *spleen* occupies its typical position behind the stomach. There is usually a disparity in the length of the pair of cæca met with in this class.

But the most remarkable exception to symmetry in the class Aves is that which exists in the *female generative organs*. The left ovary and oviduct alone are functionally evolved, whilst the right, becoming atrophied at an early period, are barely traceable in the adult animal. A few instances are on record where these right lateral homologues of the ovary and oviduct have been found evolved in functional size as a testicle and vas deferens, thus forming lateral hermaphrodism.

The *male generative organs* of birds are all symmetrical except the penis, when it exists, which is spiral.

Another instance of want of symmetry is presented by the beak of some birds, as the cross-bill, &c.

Reptiles. — The heart of reptiles is situated in the middle line, but it is not symmetrical in form, nor do the great blood-vessels enter and quit it in a perfectly symmetrical manner ; they however approach more nearly to symmetry in this class than in any of those which have been previously considered. In all reptiles there are at first two aortæ, symmetrically disposed, arching over the right and left bronchi respectively, and uniting with one another to form one trunk on the spine. The vessels given off from these are, however, most generally not symmetrical, the head and front limbs being supplied frequently from the right arch alone, and the chylopoietic viscera from the left alone. The pulmonary arteries arise behind the origin of the aortæ. The lungs of reptiles are usually two symmetrical organs, but in the Ophidia the left lung, when it exists, is much shorter than the right, and in some, as Coluber thiringicus, it is wanting altogether, the only vestige of it being a cæcal depression on the left side of the lower end of the trachea ; this absence of the left lung entails, of course, the loss of the left pulmonary vessels.

The stomach and bowels of the Chelonia, owing to the flattened form of the animals, are nearly as much laterally displaced as in the human subject. In the other reptiles they are not much out of symmetry, yet in none are they exactly symmetrical. The cardiac end of the stomach tends, though often but a little, towards the left ; the pyloric is free, and can be brought without violence to the middle line, but yet it is always found leaning to the right. This renders the spleen more conspicuous on the left. The liver of reptiles extends from side to side, but the right lobe is the largest.*

In the tadpoles of toads and frogs, I have observed that there is no gill opening on the right side. In the Lepido-siren the anus is situated on the right side of the mesial ridge of the tail.

Fishes. — The heart of fishes is posited symmetrically, but the relative position of the auricle and ventricle is usually unsymmetrical, the former being behind and to the *left* side of the latter. The single arterial trunk, with its branchial arches and the coalescing aortæ, however, are precisely alike on both sides. The intestinal canal, being generally much longer than the abdomen of the fish, is necessitated to throw itself into unsymmetrical loops and convolutions.

There is a very remarkable departure from symmetry in all the members of the group of fishes called *Pleuronectidæ*, or flat fishes, such as the turbot, halibut, sole, and flounder. These fishes lie at the bottom, and swim, on one side; and the side which they keep uppermost is coloured dark like the back of other fishes, whilst that which they keep undermost is white like another fish's belly. The dark-coloured side is also somewhat convex, whilst the white side is nearly flat. The dorsal azygos fin is continued on to the head, beyond the eyes, almost to the muzzle, and, what is most remarkable of all, both the eyes appear on the dark side, and are actually both situated on one side of the dorsal azygos fin. With the exception of the different colour of the skin, the different degrees of convexity of the two sides, and a slight distortion of the mouth, the whole of these fishes are symmetrical in all their parts, besides the eyes and the structures immediately surrounding them. The bones immediately contiguous to the eyes suffer the following remarkable distortion :— The occipital bone is almost perfectly symmetrical, and its mesial crest is continued far forward as a sagittal crest between the parietals in the real as well as the apparent middle line, supporting the styliform bones to which the rays of the dorsal azygos fin are articulated. There is a slight difference in the size of the parietals, that of the right or white side being the largest ; but it is the frontal and pre-frontal bones that suffer the greatest distortion. Arriving at the frontals, the real or primordial middle line is suddenly deflected towards the left or dark side, whilst the sagittal crest, still supporting the azygos fin, is continued straight on, on the right frontal alone. The left frontal is less expanded, but more clumsy than the right, and extends forwards in a curved form between the eyes, presenting a concavity towards the right. To this concave curve is sutured a falciform process produced from the left anterior corner of the right frontal, which is quadrate. This suture of course indicates the real middle line. The eyes are situated on each side of the septum thus formed. The end of this compound septum rests on the suture between the two pre-frontals, and this suture, which again indicates the real mesial line, presently regains the apparent middle. The right pre-frontal is much larger than the left, and comes again into contact with the right frontal on the *outside* of the right eye, which therefore occupies an orbit with a complete bony margin, whilst, the same thing not occurring on the left, the eye of that side has no orbit, but seems to lie loose in the soft structures of the cheek. The symmetry of the base of the skull is disturbed but slightly, the long sphenoid and vomer forming nearly a straight line, and participating but slightly in the abrupt deflection of the middle line which takes place above. Not the least curious part of this history is the non-participation of the dorsal azygos fin in the deflection of the mesial line : it furnishes an additional proof that its rays are not a part of the endoskeleton. The eyes of the pleuronects are of different sizes ; the furthest from the dorsal fin (the left, the one that has no orbit) being the smallest, and the optic nerve and optic lobes of the brain, which belong to it, are smaller than their fellows.*

In using the terms right and left in the above descriptions, I have constantly had in view the turbot, which is coloured, and shows its eyes on the left side; but the sole, dab, and flounder, are coloured on the right, and therefore those terms must be reversed when applied to them. It is extremely common to meet with individual specimens of Pleuronectidæ coloured, so to speak, on the wrong side, that is to say, not on that side which is usual, and the rule for the species. Turbots coloured, and having their eyes on their right sides, are frequently met with, and the flounders brought to the London market are almost as frequently coloured, and show their eyes, on the left as on the right side. The unsymmetrically posited intestines of these fishes do not participate in this transposition, but occupy, respectively, the same sides in the monstrous as in the normal individuals. The frequency of these monstrosities tempts one to conjecture that external circumstances may, perhaps, determine which side of the pleuronect shall have the eyes and be coloured.

Articulata. — The animals composing this sub-kingdom are bilateral and symmetrical. The abstract pattern or type of an articulate animal, like that of the Vertebrata, is a symmetrical figure.† From this primordial symmetry there are but few deviations, and those exceedingly trifling in amount.

Amongst the *Entozoa*, the English tapeworm (*Tænia solium*), if the flat sides be taken as dorsal and ventral, presents an instance of a-symmetry in the position of its genital orifices, which are situated on the edge of each joint, sometimes on one side, sometimes on the other, indifferently.

In the Natural History series of the Mu-

* Vol. IV. fig. 220. p. 304. art. REPTILIA.

* See fig. 409. Vol. III.

† Vol. I. Fig. 378. art. CRUSTACEA.

seum of the College of Surgeons (No. 205.), there is a portion of a tænia lata, which exhibits a monstrosity very interesting in its bearing on the question of the individuality of half segments (p. 845.). On one side, which for distinction we will call right, there are three half segments, the middle one of which unites with two half segments of the left side, leaving the upper and lower of the three right halves isolated and independent. One of these contains a generative apparatus.

Mollusca. — In this sub-kingdom absence of symmetry seems to be the rule — its presence the exception. There are great practical difficulties in the way of finding an abstract notion or type of a mollusk such as have been found for the Vertebrata and Articulata. If, however, such type be symmetrical, that symmetry is departed from much oftener than it is preserved. There is no appearance in any mollusk of a serial repetition of parts — nothing like serial homology, except in the Chitons, whose shell consists of a number of similar symmetrical transverse bands. The highest class of mollusks, the Cephalopoda, are symmetrical, and when they inhabit shells, as the Argonaut and pearly Nautilus, their shells are symmetrical. But the enormous number of species comprised in the classes Gasteropoda and Acephala are nearly all unsymmetrical. The slugs are the most symmetrical of the Gasteropoda in their external form, but here the air-orifice, for instance, is on one side.

Radiata. — For convenience of illustration, I select from among the animals composing this sub-kingdom the common star-fish. (Figs. 16, 22, &c. Vol. I. Art. Echinodermata.) This animal presents to our view a flattened form with five exactly similar rays or arms radiating from the centre, where is posited the mouth. Around the mouth is a nervous circle consisting of a number of ganglia corresponding to the arms, connected with each other by intercommunicating cords. Each arm is symmetrical in itself. Now this figure may be divided into two symmetrical halves by a line drawn across it in either of five different diameters. What is to decide which of these is to be regarded as the mesial line? Fortunately there is, on the side which is the reverse to that on which the oral orifice is placed, a peculiar spot, the remains of an embryonic structure, which is not in the centre, and will therefore serve for a datum. In certain other echinoderms the anus is situated eccentrically, in which case it also may be taken as a datum. But still a line drawn through either of these, the number of the arms not being an even number, will divide one of them in its middle on one side, and pass through the interspace between two of them on the other. This, as the arms are exact repetitions of one another, seems an unnatural and arbitrary proceeding. Still, though it possesses no natural middle line, and consequently is not bilateral, yet is the star-fish a symmetrical animal, for the idea of bilateralism is by no means included in our definition of symmetry.

Whenever a number of exactly similar parts symmetrical in themselves are arranged around a centre, whether their number be two, as in bilateral forms, or five, as in the star-fish, the whole figure is symmetrical. Abandoning then the idea of bilateralism, we may look upon the star-fish as composed of five repetitions arranged around a centre. Regarding it in this manner, we are able to institute a comparison between the form of the star-fish and that of the segmented vertebrates and articulates. The star-fish may be regarded as analogous to one segment of a vertebrate or articulate — an animal with one vertebra.

I use the term "analogous," and not "homologous," because the relation called special homology cannot be demonstrated, in any instance, between animals belonging to different sub-kingdoms. The head, the legs, the brain of an articulate, are only functionally the head, legs, or brain. They perform the same function as, but they cannot be shown to be homologous with, the head, legs, or brain of a vertebrate. Indeed I have long held that the sub-kingdoms should be limited by reference to special homology: all animals among which homologies can be pointed out — which all conform to the same type — should be grouped together to form a sub-kingdom.

The view of the analogy of a radiate animal to a vertebrate or articulate animal just given, is considerably strengthened by the manner of development of the common medusa. The larva of the medusa is a polypiform living thing, anchored by one end and tentaculated at the other. This, after a while, becomes marked with numerous constrictions, like a segmented animal, which constrictions become more and more deep until they completely divide the quondam polypiform being into a number of pieces, each of which becomes a perfect medusa. Here is a segmented animal, each of whose joints becomes an independent radiate individual; ergo, each individual is analogous to one segment of a vertebrate or articulate.

Towards a different view tends the fact, that though five, or a multiple of five, is usually the number of the rays of the star-fish, yet there are some members of the same group the number of whose arms are neither the one nor the other; for instance, there are eleven and twelve-armed asterias. Now there is such perfect constancy in the number of the parts of vertebrate and articulate segments, that that constancy seems an integral element of the idea of an archetype. There is, however, no constancy in the number of the vertebrate or articulate segments that go to constitute an animal, and therefore some may regard each arm of an asteria as analogous to a vertebra; — the common star-fish, as composed of five analogues of vertebral archetypes arranged in a circle, — as a segmented animal bent upon itself, with its anterior and posterior extremities adherent to one another. Which of these two views is the correct one — whether either is correct — can be decided then only when the true import of serial homology and of symmetry is definitely ascertained; when it is determined what is due to division, what to radiation, or whether division and radiation, one, or both, or neither, are concerned in their causation.

The skeleton of the *Velella* presents an instance of departure from symmetry, mainly in the oblique set of its vertical plate. The common medusa has a circular outline, and exhibits four quarters, which repeat one another exactly, so that it seems to be marked with a right-angled cross. The horizontal plate of the skeleton of Velella is distorted to a sub-rhomboid form, and marked with two diagonal seams that cross one another obliquely. The longer one of these diagonals is produced upwards so as to form the oblique sail-supporting vertical plate, which also presents a seam continued up from the point of crossing of the diagonals, indicating that it is composed of two parts uniting at this central point. This de facto unsymmetrical radiate is therefore easily reduced in idea to its primordial symmetry.

Infusoria. — Out of the vast number of various forms met with amongst these animalcules the greater number are symmetrical. This symmetry is usually not bilateral, but that of the star-fish. There are, however, some forms which are quite irreconcilable with symmetry, which no line can divide into two similar halves, which are one, and present no repetitions of parts; except, indeed, when they are undergoing fissiparous generation.

Antero-posterior Symmetry. — By reference to the diagram at page 824. Vol. III. Fig. 433., representing the abstract notion or type of a vertebral segment, it will be seen that the upper or posterior half is a reverse of the lower or anterior. Referring to what really exists in nature, we find, in the caudal vertebræ of fish, that their dorsal and ventral halves are counterparts tolerably exact, yet that exactness is not nearly what exists between the lateral halves. If an antero-posterior as well as a lateral symmetry be admitted, then we have four repetitions arranged around a centre. At all events there is here, in the Vertebrata, some amount of evidence of radiation or divergence from a central axis comparable in some degree to what we see in the Radiata. The anterior and posterior parts of vertebral segments, as found in nature, are usually extremely dissimilar. The rays of the dorsal and abdominal (anal) azygos fins of fishes are antero-posterior repetitions, but the fan-like tail fin, which in most fishes seems to be remarkably symmetrical antero-posteriorly, half of it apparently belonging to the dorsal and the other half to the abdominal moiety of the fish, usually belongs, as I have observed in the typical fishes, cyprinoid, &c., in reality, entirely to the abdominal or under moiety. The embryo of these fishes at first has a tail like an eel, into which the spinal column is continued nearly to its tip. A little way from the extremity of this, on the abdominal aspect, a group of fin rays are soon observed to sprout out meanwhile that the end of the vertebral column shrinks and turns up. The group of fin rays grows, and the vertebral column shrinks, so that in time the former is brought to form the fan-like extremity of the animal; but even then the atrophied end of the vertebral column may be detected occupying the upper edge of the fan. Even in the adult fish some trace of this original relation of the tail fin can be detected. If the tail of an adult homocercal fish be macerated or boiled, and all the pieces which are not anchylosed to it be removed, what remains will not be symmetrical, but will terminate by turning or cocking up. Even in the Pleuronectidæ, whose tails seem to be remarkably symmetrical, and where the spinal column seems to terminate in a flat triangular piece, it will be found that the lower half of this piece can be easily removed, whilst the upper half forms one piece with the body of the last vertebra, with which, in fact, it forms a coccyx composed of numerous degenerated and consolidated vertebræ.

Symmetry of Disease.—This subject has been most ably treated by Dr. W. Budd *, of Bristol. Those local diseases, the cause of which is in the blood, usually affect the solids of the body symmetrically. This can be often well observed in lepra, psoriasis, secondary syphilis, gout, and rheumatism, and in the eruption caused by taking the iodide of potassium. It is due, no doubt, to the symmetrical disposition of those tissues for which the morbid poisons have a peculiar affinity. It proves, moreover, that there is more of peculiarity in certain parts of organs than what meets the eye, which peculiarity is symmetrical. For, though the tissue of all parts of a bone, for instance, shall be exactly the same, it shall be diseased at a certain part only, and the disease shall be repeated in exactly the same part of the corresponding bone of the opposite side. Connected with this is the observation made above, that the corresponding points of both sides of the body are exactly of the same age — have reached a certain stage of development at exactly the same time. But the force of this observation in explaining the symmetry of disease is considerably weakened by another fact noticed by Dr. W. Budd, namely, that the diseases above named are apt also to localise themselves in parts that are serially homologous, or corresponding in the upper or lower limbs, as the knee and elbow, wrist and ankle; for these parts, though homologous, are not of the same age. It is well known that the development of the upper and lower limbs does not proceed *pari passu*. There is here, at least, some determining agency more mysterious than mere age. Still more curious and mysterious is the relation of the eruption called shingles to the bilateralism of the body. It often extends zone-like around one half, stopping exactly at the median line before and behind,

* Medico-Chirurgical Transactions for 1842.

and thus seemingly affording evidence of that individuality of one half of the body which was spoken of as a feasible opinion above.

PLANTS. — The leaf of the higher plants, which is the unit or individual of botanists, is bilateral and symmetrical — always in idea, generally in fact. These leaves are associated together to form buds, branches, flowers, or fruits, in whorls. Symmetrical figures are often produced by these associations, but yet the pattern is spiral. In watching the development of spores of conferva, they are seen, whilst still but single cells, to shoot out in various manners, the majority of which are quite irreconcilable with symmetry, either bilateral or radiating. Whatever may be its import, it is quite certain, from the very nature of symmetry, that the cause of it must be internal, that is to say, within the body in which it is manifested. But it has been conclusively determined, by experiments, that external influences, acting upon them in certain directions only, such as light, heat, and gravitation, exert a considerable power in determining the form of vegetable productions. Animals, doubtless, are also greatly affected by these agencies, yet, as they enjoy the faculty of locomotion whereby all parts of them are successively turned towards the directions from which these forces emanate, the form impressed upon them by internal causes, suffers little or no distortion therefrom; but plants, being destitute of locomotion, continually receive these influences in a partial manner, and consequently we the less expect to meet with symmetry among them. Whenever their internal forces tend to make them symmetrical, the partial action of external agents is apt to disturb their symmetry. It is this, probably, that renders the germinating conferva cell unsymmetrical.

CRYSTALS of unorganised matter are spoken of as symmetrical. The symmetry, however, which they exhibit is not a bilateral symmetry. It consists of the repetition of the same angles and facets at the poles of an axis, but the repetitions are not reverses. The reader may illustrate my meaning by cutting a rhomboid in paper, when he will observe that each of its angles and sides are twice repeated, but he will find it impossible to fold it so that one half shall coincide with the other.

The precise import of the symmetry of organised bodies is, as repeatedly indicated above, as yet involved in mystery. Albeit a fact so evident, so constantly obvious to our senses, as often, like gravitation, to pass unheeded, it is a great and an important fact, — a fact of the same order with those which have already led to the establishment and demonstration of grand, comprehensive, and unassailable theories — the bright triumphs of the human intellect, that have reduced to order, simplicity, and connexion, what before was all confused, complicated, and disjointed, — a fact, therefore, that inspires us with hope for our, as yet, imperfect science of anatomy. It seems to tell of radiant forces, of certain, definite, mathematical, and inexorable laws, concerned in the production of animals. Taken with the other important fact — serial homology, it seems to suggest for the development of Vertebrata and Articulata the multiplication of centres in a serial line — of centres of radiant force, that then proceed to induce the surrounding particles to arrange themselves in a symmetrical figure. In truth, as the mind contemplates this fact, various theories pass before it, yet shadowy, changeable, and indistinct as a phantasmagoria. One day, perhaps, some one of these shall meet with definite enunciation and clear demonstration; at present we must be content with putting the fact of symmetry prominently forward and exhibiting it in various points of view, with declaring it an important fact, and not a matter of course.

(S. R. Pittard.)

SYMPATHETIC NERVE.—(See SUPPLEMENT.)

SYMPATHY (*συν-παθος*).— Sympathy may be defined as the assumption by different individuals, or by different parts of the same individual, of the same or an analogous physiological or pathological state at the same time, or in rapid succession. It is popularly known that the act of yawning, performed by one individual in a company, is apt to induce in many of the others an irresistible tendency to the same act. In a similar manner, the excitement of certain emotions (mirth or sadness, laughter or tears) is apt to spread through an assemblage of persons with extraordinary rapidity. The power of eloquence, of music, or of spectacle, to produce such effects, is witnessed every day in places of public resort, whether for devotion, business, or amusement.

Many instances are known in which convulsions have been excited in persons not previously subject to them, by the sight of a patient in an epileptic fit. And peculiar nervous disorders, of a convulsive kind, have been found to affect nearly all the members of a community without the slightest evidence of their being contagious or infectious. An impression upon an organ of sense may produce effects very different in their nature to any thing which could be anticipated; and these many be purely of a physical kind, or they may act primarily upon the mind. Thus certain odours will induce syncope in some people; and the smell of a savoury dish to a hungry person, or even the mention or the thought of a meal, will excite a flow of saliva. The emotion of pity excited by the sight of some object of compassion, or by a narrative of a mournful kind, will produce a copious flow of tears.

All such phenomena are said to result from Sympathy. When one yawns, immediately in consequence of another's yawning, the former evidently and truly sympathises with the latter; and the convulsions which are induced by the sight of another in a fit, are not less sympathetic. The individual in whom the convulsions are induced, sympathises with the other. Such obvious instances of sympathy between different individuals led to the supposition of some such similar consent between different or even distant parts in the same person.

Motions or sensations caused in certain parts, in consequence of a primary irritation of other and distant parts, are of the sympathetic kind. These motions or sensations are produced in, as it were, an indirect or circuitous manner, or one different from that in which they are ordinarily excited.

Thus a stimulus to the olfactory membrane causes a peculiar affection of the sense of smell, and occasions that depression of the heart's action, from which results a state of syncope. Or another affection of the same sense causes a suddenly increased action of the salivary glands.

If we analyse any one of these examples of sympathetic actions, it will appear that three circumstances may be noticed in the production of the phenomena: 1st, the primary exciting cause, which may be an object presented to the mind through one of the organs of sense, or causing an impression upon any sensitive nerve, and therefore upon some part of the centre of sensation; 2ndly, the part affected directly by this primary stimulus; and, 3rdly, the action or sensation resulting from the affection of this part.

Many other sensations or motions may be enumerated besides those above referred to, whether occurring in health or in disease; and we shall give examples of these before we discuss this subject further.

The examples of sympathetic *sensations* which may be adduced are chiefly of the morbid kind. Pain is felt at a certain part, in consequence of an irritation in another part distant from it, and apparently altogether unconnected with it. A familiar instance of this is pain in the knee from disease of the hip-joint. So marked in some instances is the pain in the knee, and so much has it absorbed the patient's attention, that the real seat of the disease has been overlooked, and the remedies been applied exclusively to the knee. Pain in the right shoulder, from disease of the liver, is a sympathetic sensation of similar kind; and sometimes the hepatic irritation causes pain over a more extensive surface. Whytt mentions, that, in two cases of suppuration of the liver, he had seen the patients "affected with a numbness and debility of the right arm, thigh, and leg." Sometimes both shoulders are the seat of pain, from hepatic irritation.

The peculiar sensations felt in the teeth from a noise which grates upon the ears, is sympathetic of the irritation of the auditory nerve. Practitioners are well aware how many morbid sensations in parts remote from the intestinal canal may be cured by the removal of scybala or other accumulations from it. Painful affections of the nerves of the face, and of other parts, are often due to a cause of this kind. The irritation of a stone in the bladder gives rise to pains in the thighs, or to itching at the end of the penis; and uterine irritation, whether from disease or from the enlargement of that organ in connection with the early stage of pregnancy, causes similar pains in the nerves of the thighs.

Headache and defective vision are frequently produced by disordered stomach. A draught of very cold water, or ice, taken quickly into the stomach, may occasion acute pain in the course of either frontal nerve. This same nerve on one side is frequently the seat of pain after the imprudent use of acid wines or other fermented liquors.

Movements, excited by the operation of a stimulus applied at a distance, form a large proportion of the instances of sympathetic phenomena. All the ordinary physical nervous actions in which motions are excited by stimulating a sentient surface, may be regarded as examples of sympathetic actions.* The contraction of the iris upon the application of the stimulus of light to the retina, or of the pharyngeal muscles by stimulating the mucous membrane of the fauces, are instances in point where the stimulus acts indirectly upon the contracting fibre. Nothing is more sure than that in these instances the change wrought by the stimulus in certain sentient nerves, travels by a circuitous route through a nervous centre to the muscles which are called into action. Akin to these actions are the forcible respiratory movements which may be excited by irritation of the tracheal membrane, as coughing; or sneezing, by stimulating the nasal membrane; or vomiting, by irritating the fauces. Spasmodic affections are often instances of morbid actions in sympathy with intestinal irritation, or the irritation of teething in children. Partial or general convulsions are very frequently due to either or both these causes. We have known the most violent opisthotonos co-existing for a considerable time with the presence of lumbricoid ascarides in the intestine; but ceasing immediately on the removal of the worms. Vomiting is commonly sympathetic of diseased kidney, or of the passage of a calculus along the ureter; or of the passage of a gall-stone along the gall duct; or it may be induced by the introduction of a catheter into the urethra.

The consentaneous action of symmetrical parts is no doubt due to a similar cause to that by which most of the sympathetic actions are excited, and more especially in those parts where symmetry of action is constant, although liable to be interrupted by the influence of the will.

A distinct class of sympathetic actions consists of those in which certain parts enlarge or become developed simultaneously with, and to a certain extent in effect of, the increase

* It has been remarked, that the term "sympathetic *actions*" involves a contradiction. But it may be observed, that the contraction of the muscles, on which the action depends, is only the natural mode in which that class of vital organs can manifest their consent with certain states of nervous centres, or of sensitive nerves. The action is the result of the state which the muscle assumes in sympathy with the stimulated nerve. The contradiction is therefore apparent, not real.

of others. The penis, the beard, the vocal organs, experience a marked increase of development at the adult period of life simultaneously with the enlargement of the testes; and, it may be added, in effect of their increase, because the early removal of these organs prevents the growth of the others. And so likewise as the ovaria are developed, the uterus, the vulva, the mammæ, increase in size; the ovarian and uterine irritation which accompanies the menstrual flux causes enlargement of the breasts, which subsides as soon as that period has gone by.

The various examples enumerated in the preceding paragraphs may be classed under three heads: first, sympathies between different individuals; secondly, those which affect the mind, and, through it, the body; and, thirdly, those which are strictly organic, and therefore physical.

Of the first class of sympathies we can offer no physical explanation. Whether the nervous system of one individual can directly affect that of another, or whether the effect is produced on the imagination, and afterwards on the nervous system, are questions still *sub judice*. The serpent fascinates his prey, apparently by the power of his eyes, and it is well known that one man can exert a marked control over another by a mere look; and in the same way man can control other animals, even the fiercest carnivora, by a firm and decided glance of the eyes. It is no explanation of sympathetic phenomena of this kind to ascribe them to the effect of a tendency to imitation. Imitation is voluntary; these actions are involuntary, or take place even in despite of the will.*

In the second class of sympathetic phenomena, an affection of the mind is a necessary link. But why that affection of the mind should produce its peculiar effect is a question difficult to solve. Why should the perception of certain odours produce in one case increased action of the salivary glands, and in the other case cause syncope? The only reply which can be made to this question is, that in these instances the impression on the sensorium causes a change there analogous to that which an original affection of the mind of similar kind would produce, and therefore gives rise to effects of the same nature as those resulting from that mental change. Thus the smell of savoury food excites in the mind the idea of food, which in a hungry man would, if it occurred spontaneously, occasion a flow of saliva. And the odour which occasions syncope, creates in the mind an emotion of disgust, which, if it arose independently of the physical impression, would affect the heart through the centre of emotion. It is plain, however, that that portion of the nervous centre which is affected in such cases, must have a direct influence upon the parts in which the sympathetic phenomena appear; and this through commissural fibres, or the continuity of its gray matter with that of the centre from which its nerves immediately spring; thus, in the instances referred to, the centre of sensation, which is first affected, is, through the medulla oblongata, connected with the salivary glands by the fifth nerve, and with the heart by the vagus.

We derive an explanation of the third class of sympathetic phenomena from the known laws of sensitive and motor nerves. It is known that stimulation of a sensitive nerve at its origin, or in any part of its course, will give rise to a sensation which will be referred to the peripheral extremity of the stimulated fibres; and that a stimulus applied to a motor nerve causes a change in it which spreads peripherad from the point stimulated, and therefore affects the muscular parts with which it is connected. It is known also, that a sentient nerve may excite a motor or sensitive nerve which is implanted near to it in the nervous centre — doubtless through the change which it produces in that centre; nor can it be doubted that a sensitive nerve may receive such a powerful stimulus as to exalt the polar force of a large portion of the nervous centre in the neighbourhood of its insertion, and thus to excite a similar change in all the nerves, whether motor or sensitive, which are connected with it. Thus, according to the intensity of the original stimulus, there will be a radiation of nervous force from the centre, either in one or two motor or sensitive nerves, or in several such; and the number and variety of the sympathetic phenomena will thus depend on the intensity and extent of the change in the nervous centre excited by the primary stimulus.

To explain, then, the phenomena of sensation and motion under consideration, we must determine the individual nerves affected in each instance, and ascertain what connexions they have with each other. We learn from anatomical investigation, that, although nerves anastomose with each other in their distribution, this anastomosis is by no means of that kind which would justify the supposition that an irritation could be communicated from one to the other in their course. The nerve-fibres only lie in juxtaposition, but do not communicate; and there is an evident provision in the tubular membrane and white substance of Schwann for the insulation of the central axis, which is probably the effective substance in the nervous action. We must seek, therefore, in the nervous centres for such a communication between these nerves as may explain the excitability of one by the other. In the present state of our knowledge we can do no more than state it as in the highest degree probable that nerves implanted in the centre immediately contiguous to each other can exert an influence upon the vesicular matter of the centre, and upon each other.

But there are certain facts which demonstrate beyond all doubt, that, in such actions as we refer to, the integrity of the centre forms a necessary condition. First, in many of the instances it is plain that there can be no connexion between the affected nerves elsewhere than in the centre, for they are so distinct from each other that there is not even

* Bostock's Physiology, vol. iii. p. 227.

that apparent connexion which results from the anastomosis of a fasciculus of fibres of the one with a portion of the other. Secondly, the removal of the portion of the nervous centre with which any one of the nerves concerned in the sympathetic action is connected, will prevent the development of the phenomenon, although the nerves themselves remain uninjured in their peripheral distribution, or in their connexion with each other. Thirdly, if there were any peripheral communication between nerves, it would be most likely to take place in the plexuses. Experiments, however, upon the nerves which lead to these show that each nerve-tube, in its passage through them, retains its isolation as distinctly as in any other part of its course. The three nerves which supply the lower extremity in the frog, says Müller, form a plexus from which two nervous trunks issue: if one of these latter be divided and isolated from all its connexions with muscles, and the portion of it connected with the plexus irritated, the impression will be transmitted in the centripetal direction by the sensitive fibres of nerve; but the motor fibres of the other nerve arising from the plexus are not affected, and excite no contractions in the muscles to which they are distributed.*

In applying these principles to the explanation of the instances which we have quoted, we shall find it difficult to determine the central connexion in some, although in others such a connexion is highly probable. It remains, therefore, for future anatomical research to ascertain what that connexion is which enables one nerve to sympathise with another. In the instance of pain in the shoulder in sympathy with irritation of the liver, the hepatic irritation excites a change in some sensitive nerves, which is propagated to the centre, and there affects some of the sentient fibres distributed in the region of the shoulder. The phrenic and the external thoracic nerves are both or either of them, but more especially the former, favourably situated to constitute the excitant of such a sympathetic sensation. The phrenic nerve of the right side is largely distributed upon the peritoneal surface of the diaphragm, and upon the inferior vena cava, and forms many connexions with the hepatic plexus in the substance of the liver. It may therefore readily participate in any irritation of that organ. Now, the phrenic nerve is implanted in the spinal cord on a level with the third or fourth cervical nerves; and the nerves of the shoulder form their connexion with this central organ about the same level. The origins of these nerves, therefore, are sufficiently contiguous to each other to warrant the belief that an irritated state of one may be propagated to the other through the vesicular matter of the centre. But it may be inquired why the irritation is limited to sensitive nerves of the shoulder; and why movements are not excited by the stimulation of the motor fibres of the phrenic itself, or of other nerves. The limitation of the irritation to one or two nerves depends on the degree of the stimulus, and the absence of any movements is due to the disposition of the phrenic nerve on the surface being unfavourable for the excitation of motions by irritation of its peripheral branches. And the experiment cited from Müller, in the last paragraph, shows that simple irritation of the *trunk* of a compound nerve in connexion with the centre is not sufficient to produce motion; which requires probably either a more prolonged and violent irritation of the nerve, or a polar state of the centre in which it is implanted.

* Baly's Müller, vol. i. p. 756.

Some of the instances of sympathetic sensations, referred to above, do not admit of an explanation so obvious. The pain over the brow from ice or cold water in the stomach may be referred to irritation of the gastric branches of the vagus, communicated in the medulla oblongata to the fifth; but why the irritation should be limited to the ophthalmic division of the fifth cannot be accounted for in the present state of our knowledge.

In those sympathetic movements which are of ordinary and normal occurrence, two provisions seem to be secured, namely, a certain peripheral organisation of the excitor nerve, and a certain central relation between it and the motor nerve. But in those which are of a morbid kind, it is necessary to suppose the existence of a more or less exalted polarity of the centre in order to explain the phenomena fully. This polar state will continue in many instances even after the primary peripheral irritation has been removed, as in tetanus, or in the convulsions from intestinal irritation; and we learn from this fact the importance in practice of attending to the state of the nervous centre, as well as to the removal of the irritating cause.

There are other sympathetic phenomena, of the physical kind, in which, however, the nervous system does not appear to take a prominent part. Such are the changes which occur in different and distant organs in connexion with a particular period of life, or the development of a particular function. Among these are the phenomena of puberty in both sexes; the enlargement of the mammæ in pregnancy. Whatever part the nervous system may take in such changes, it is impossible to account for them by reference to that system only; they must rather be regarded as phenomena of nutrition occurring in harmony with the laws of growth, and therefore affecting the vital fluid more particularly than any part of the system of solid parts.

Continuity of texture disposes, as is well known, to the extension of a diseased state originating at some one point. So also does *contiguity*. Phlegmonous inflammation of the areolar tissue, and erysipelas in the skin, spread with great rapidity. Inflammation arising in one of the opposed surfaces of a serous membrane readily attacks the other. These effects have been vaguely assigned to sympathy (the *continuous* and *contiguous* sympathy of Hunter). But it cannot be supposed that the nervous system takes part in the production of such phenomena, which ought rather to be ascribed, in the one case, to the continuity of blood-vessels, and, in the other, to contamination either by effused fluids or by morbid blood. (*R. B. Todd.*)

SYNOVIA is that fluid which exists within the membrane lining joints, to assist motion by lubrication; as also in the bursæ. The membranes generally, which line the various cavities of the body, are lubricated by fluid. This varies in character according to circumstances; and among these perhaps none more tend to the requirement of especial conditions than that of active and frequent motion, involving friction of the surfaces so lubricated.

Thus we find that the fluid of the pericardium differs essentially from that of the ventricles of the brain; while again the synovia, supplying moisture to the joints, varies greatly from the fluid of the pericardium, probably in order to assist the opposed surfaces in bearing friction in an exaggerated degree. The word attrition appears, indeed, the most appropriate to the conditions relieved by the presence of synovia, placed as it is between surfaces occasionally strongly approximated either by superincumbent weight or muscular contraction.

Synovia was chemically examined by Margueron.* The specimen he analysed was viscid, and became gelatinous soon after it was obtained. It then deposited a fibrous matter, and became clear above. Though the analysis of Margueron was not conducted on the more exact principles characterising those of the present day, it still serves to show that the specimen was peculiar as an animal fluid, and differed in one respect from the fluids generally, which lubricate surfaces. Thus it appears that as much as 11·86 per cent. was composed of fibrinous matter (fibrin), which coagulated, as stated before, soon after the fluid was obtained.

Margueron's analysis is as follows:—

Fibrin - - - - -	11·86
Albumen - - - - -	4·52
Chloride of Sodium - -	1·75
Soda - - - - -	0·71
Phosphate of Lime - -	0·70
Water - - - - -	80·46
	100·

Synovia has of late years been examined by John.† It is described as a viscid transparent yellowish or reddish fluid, resembling in its odour the serum of the blood. The analysis is stated as follows:—

Water - - - - - -	92·80
Albumen - - - - - -	6·40
Extractive Matter, Chloride of Sodium, and Carbonate of Soda - - - - - -	0·60
Phosphate of Lime - - -	0·15

It will be seen that these two analyses vary greatly — they were not made, it must be recollected, at the same date; and the methods of animal analysis are greatly improved since Margueron published. There is, however, an important point in which both analyses agree, viz. in stating phosphate of lime among the constituents of the fluid. John makes no mention of the existence of a coagulable fibrinous matter; a fact of much importance, which it appears desirable carefully to inquire into, insomuch as it is very possible the analyst may have extracted the synovia after coagulation had occurred within the membrane, and so obtained the clear fluid only; while Margueron may have been fortunate enough to secure it before such change had taken place, and in its natural condition.

With regard to this subject, on which our knowledge is but scanty, it appears still of importance to reflect on the material before us; and it is matter of no small interest to consider how far the results of peculiar mechanical conditions are modified by variations in the character of lubricating fluids, knowing, as we do, that, while the ventricles of the brain, subject to agitation only, contain no albumen in their lubricating fluid, the liquor of the pericardium contains that principle in abundance; and that in the synovial fluid adapted to the lubrication of the joints, we have, in addition to albumen, not only a considerable proportion of phosphate of lime, but probably fibrin also, as a necessary constituent. (*G. Owen Rees.*)

TASTE.—The sense by which we distinguish the *sapid* properties of bodies. The term, as commonly understood, includes much more than this; being usually employed to designate the whole of that knowledge of the qualities of a body (except such as is purely tactile), which we derive through the sensory apparatus situated within the mouth. But it will be hereafter shown that a considerable part of this is dependent upon the assistance of the *olfactive* sense; which is affected, through the posterior nares, by the odorous emanations of all such bodies as are capable of giving them off; and the indications of which are so combined with those of the true gustative sense, as to make an apparently single impression upon the sensorium. Moreover, there are certain sensorial impressions received through the organ of taste, which are so nearly allied in their character to those of *touch*, as to render it difficult to specify any fundamental difference between them: such are the *pungent* sensations produced by mustard, pepper, the essential oils, &c.; all of which substances produce a sensation when applied for a sufficient length of time to any part of the cutaneous surface, which can scarcely be distinguished from that excited through the organ of taste, in any other way than by its inferior intensity, and by the absence of the concurrent odorous emanations. The *taste* of such substances might, perhaps, be considered, therefore, as the composite re-

* Ann. de Chimie, xiv.

† Simon's Animal Chemistry. Trans. Sydenham Society.

sult of the impressions made upon the sensorium through a refined and acute *touch*, and by the effect of their odorous emanations upon the organ of *smell*. After making full allowance, however, for all such as can be thus accounted for, there remains a large class of pure *sapors*, of which we take cognizance without the assistance of smell, and which are altogether dissimilar to any tactile impressions: such are the bitter of quinine, the sour of tartaric acid, the sweet of sugar, the saline of common salt, &c. The smell can give us no assistance in distinguishing small particles of these bodies, since they are either entirely inodorous, or so nearly so as only to be recognizable through its means when in large masses; and the most refined touch cannot afford any indication of that kind of difference among them, of which we are at once rendered cognizant by taste. Still the gustative sensations scarcely differ more from the tactile than some of these last differ among each other,—the sense of heat and cold, for example, from the simple sense of contact or resistance; and we shall find that the analogy between these two senses is so strong, both as to the conditions under which they are respectively exercised, and the structure of the apparatus through which the impressions are received, that they must be regarded as much more nearly related to each other than either of them is to the other senses, or than the latter are amongst themselves.

The seat of the sense of taste is always at the entrance to the alimentary canal; and its purpose is obviously to afford a means of discrimination among the substances introduced into the mouth as food. The surface of the tongue is undoubtedly the special organ of taste in the higher animals; but there is adequate evidence that the sense is not entirely restricted to that organ, even in man; and it would seem improbable, considering the obvious purpose of the sense, that it should be wanting in that very large proportion of the animal kingdom in which no tongue exists, or in which the surface of that organ is so hard and horny as to forbid our attributing to it the possession of gustative sensibility. Without affirming (with Magendie) that the specific gustative sensibility extends over the teeth, the gums, the palate, and the pharynx, we feel justified in stating that in most persons it is distinctly present on the surface of the soft palate, especially in the neighbourhood of the uvula, and on that of the arches of the palate and of the fauces; and in a less degree on the surface of the anterior part of the soft palate. In making experiments upon this point, as well as upon many others connected with the sense of taste, it is important to bear in mind that if aromatic substances be employed, the impressions derived through the sense of smell may confuse the result; and also that if the sensory surface be too much exposed to cold air, its sensibility will be greatly diminished. Further, it should be borne in mind that a considerable amount of individual difference may not improbably exist, both as to the extent of the gustative surface, and the relative acuteness of the sense in different parts.

Conditions of the Sense of Taste.—In order that gustative impressions may be communicated to the sensorium, the first requisite is an afferent nerve, endowed with the power of receiving and transmitting them. The gustative surface in man and the higher animals being supplied by two afferent nerves,—the glosso-pharyngeal, and the lingual branch of the fifth pair,—we shall have to inquire whether both of these are subservient to the sense of taste, as well as to that of touch; or whether, as in the case of the organs of smell, sight, and hearing, there is one nerve of *special* and another of *general* sense. The peripheral extremities of both these nerves are in relation with a *papillary* apparatus, in which they are elevated above the general surface, and come into close proximity with capillary loops; and here, as elsewhere, it appears certain that the neighbourhood of circulating blood is an essential condition for the reception of sensory impressions. For the gustative nerve-fibres to be impressed by the distinctive properties of sapid substances, it would further seem requisite that these substances should be brought into immediate relation with them, and that they should penetrate, in the state of solution, through the investments of the papillæ, into their substance. This would seem to be proved by the two following facts: first, that every substance which possesses a distinct taste is more or less soluble in the fluids of the mouth, whilst substances which are perfectly insoluble do not make their presence known in any other way than through the sense of touch; and, second, that if the most sapid substance be applied in a dry state to the papillary surface, and this be also dry, no sensation of taste is excited. Hence it may be inferred that, in the reception of gustative impressions, a change is produced in the molecular condition of the nerve-fibres, or, to use the language of Messrs. Todd and Bowman, their polarity is excited, by the direct agency of the sapid matter itself. This change may be induced, however, both by electrical and mechanical stimulation. If we make the tongue form part of a galvanic circuit, a peculiar sensation is excited, which is certainly allied rather to the gustative than to the tactile, and which does not seem to be due (as at one time supposed) to the decomposition of the salts of the saliva. And, as Dr. Baly has pointed out*, "if the end of the finger be made to strike quickly, but lightly, the surface of the tongue at its tip, or its edge near the tip, so as to affect not the substance of the organ, but merely the papillæ, a taste sometimes acid, sometimes saline, like the taste produced by electricity, will be distinctly perceived. The sensation of taste thus induced will sometimes continue several seconds after the application of the mechanical stimulus."

* Translation of Müller's Physiology, p. 1062, *note*.

On the other hand, as Wagner has truly remarked, if the surface of the tongue near the root be touched with a clean dry glass rod, or a drop of distilled water be placed upon it, a slightly bitterish sensation is produced; and this, if the pressure be continued, passes into that of nausea, and if the pressure be increased even excites vomiting. The feeling of nausea may be excited by mechanical irritation of any part of the surface of the fauces and soft palate; and this feeling is certainly much more allied to that of taste than to that of touch. Further, it has been observed by Henle, that if a small current of air be directed upon the tongue, it gives rise to a cool saline taste like that of saltpetre. Thus we find that the peculiar effects of sapid substances upon the nerves of taste may be imitated to a certain extent by other agencies; and it also appears that the sensations excited by these vary according to the part of the gustative surface on which they operate; mechanical or electrical stimulation of the front of the tongue giving rise to a kind of saline taste, whilst mechanical stimulation applied to the back of the tongue and fauces excites the feelings of bitterness and nausea.

One of the conditions requisite for the due exercise of the gustative sense, is a temperature not departing far on either side from that which is natural to the body. It appears from the recent experiments of Prof. E. H. Weber *, that if the tongue be kept immersed for nearly a minute in water of about 125°, the taste of sugar brought in contact with it, either in powder or solution, is no longer perceived; the sense of touch, usually so delicate at the tip of the tongue, being also rendered imperfect. A similar imperfection of taste and touch was produced by immersing the tongue for the same length of time in a mixture of water and broken ice.

Nerves of Taste.—Much controversy has taken place upon the question whether or not there be a special nerve of taste; and whether the lingual branch of the fifth pair, or the glosso-pharyngeal, possesses the best claim to this title. The principal points of this controversy have been already noticed [See FIFTH PAIR and GLOSSO-PHARYNGEAL]; a short review of it, however, with a notice of the most recent inquiries on the subject, will be here desirable. That the *glosso-pharyngeal* is the special nerve of taste, and that its complete section on both sides destroys the sensibility to gustative impressions, was first affirmed by Panizza; and his conclusions, adopted by Dr. M. Hall and Mr. Broughton †, have been since, to a certain extent, supported by the experiments of Valentin ‡ and Bruns.§ The grounds on which this doctrine rests are briefly as follows:—After recovering from the depression which is the immediate consequence of the operation, a dog whose glosso-pharyngeal nerves have been divided is said to eat pieces of meat rendered bitter with colocynth, and to drink milk and water dosed with the same drug, without any repugnance; whereas if the lingual nerves be divided and the glosso-pharyngeals left entire, the bitter morsel is rejected as soon as it reaches the back of the mouth, although it may have been at first seized very hastily. But, on the contrary, it has been affirmed by Kornfeld *, with whom Müller and Gurlt were associated, by Dr. Alcock †, by Dr. John Reid ‡, by Guyot and Cazalis §, by Magendie ||, by Longet ¶, and by Volkmann and Bidder **, that distinct indications may be obtained of the persistence of the sense of taste, after complete section of the glosso-pharyngeal nerves on both sides. Of a dog in which the nerve had been divided before giving off a single filament, Dr. J. Reid states:—"I have repeatedly fed that dog with morsels of animal food from my hand; and after he had taken several morsels in this way, which he readily swallowed, I then presented a morsel similar in size to the others, and with the colocynth, concealed in a way that he could not see it; but no sooner was it taken into the mouth than it was rejected with evident symptoms of disgust. This was repeated more than once." Bidder found that although two dogs whose glosso-pharyngei had been divided, swallowed pieces of flesh soaked in an infusion of colocynth, which another dog whose nerves were uninjured at once rejected, yet certain movements of the lips and tongue were observed, which showed that these were not altogether relished. It is obvious that, in such an inquiry, positive evidence of the continuance of the sense of taste is more conclusive than the negative evidence from which its absence may be inferred. It is right to bear in mind that, as Wagner has pointed out, dogs when they are hungry will devour meat however strongly seasoned with bitter drugs, though all their nerves be entire. Dr. Reid makes the remark, in explanation of the results of Panizza, that one of the dogs on which he had divided the glosso-pharyngeal nerves, would eat the morsel of meat containing colocynth, rather than lose it, when very hungry; though he refused it, if he saw any prospect of procuring another free from the bitter. Wherever any such evidence of the persistence of the sense of taste was obtained, this appeared specially to exist in the *anterior* portion of the mouth.

* Müller's Archiv. 1847, S. 342.

† Sixth Report of British Association; p. 125 of Transactions of Sections.

‡ De Functionibus Nervorum Cerebralium, &c., 1849, p. 41.

§ De Nervis Cetaceorum, Tüb. 1836; quoted by Müller.

* De Functionibus Nervorum Linguæ Experimenta. Berol. 1836.

† Dublin Journal of Medical and Chemical Science, 1836.

‡ Edinb. Med. and Surg. Journal, Jan. 1838.

§ Archives Générales de Médecine, 1839.

|| Leçons sur les Fonctions du Système Nerveux, 1839, tom. ii.

¶ Anatomie et Physiologie du Système Nerveux, 1842, tom. ii. p. 225.

** Articles *Nervenphysiologie* and *Schmecken* in Wagner's Handwörterbuch der Physiologie.

On the other hand, it has been maintained by some physiologists (especially Magendie, Müller, Gurlt, and Kornfeld), that the *lingual branch of the fifth pair* is the special nerve of taste ; although Müller does not altogether exclude the participation of the glosso-pharyngeal as having a share in the transmission of gustative impressions from the posterior part of the tongue and the fauces. The experiments of Dr. Alcock and others, however, appear to show that very distinct indications of gustative sensibility are presented by animals in which this nerve has been divided, the sense being merely deficient in the anterior part of the tongue.

On the whole, then, it may be concluded from experiment, that the glosso-pharyngeal nerve and the lingual branch of the fifth pair minister alike to the sense of taste; the former being concerned in the transmission of gustative impressions from the fauces and the posterior part of the tongue, and the latter from the anterior portion of the tongue ; and the former being the special recipient of the impressions which produce the sense of nausea. This inference is so completely in harmony with the results of anatomical inquiry, that it may be considered as having a very strong claim to reception as a physiological truth. The branches of the glosso-pharyngeal appear to constitute the sole nervous supply of that region at the base of the tongue, of which the circumvallate papillæ form the centre, and also of the sides of the tongue near the base. As it is universally admitted that these parts are acutely endowed with gustative sensibility, we cannot help regarding the glosso-pharyngeal nerve as its instrument. On the other hand, the middle and anterior parts of the dorsum of the tongue appear to be solely supplied from the fifth pair, —the tip, however, receiving a branch from the glosso-pharyngeal, which runs towards it, along the under surface. It has been denied by some physiologists that the central portion of the upper surface possesses the proper gustative sensibility; but we fully coincide in the statements of those who maintain the affirmative: and although it must be admitted that the sense is not so acute as it is at the base, sides, and apex of the tongue ; yet this may be fairly attributed to the greater thickness of the epithelial investment, and to the predominance of the conical papillæ over the fungiform in the central region.

On turning to the pathological evidence which bears upon this question, we find an apparent contradiction in the phenomena recorded by different observers; but this is in a great degree removed by a more careful examination; and the evidence on the whole preponderates in favour of the preceding conclusions. We shall make use of the excellent summary recently put forth by Dr. J. Reid * : —"In the single cases observed and recorded by Mayo, Serres, Romberg, Mr. Bishop, and Todd and Bowman, and in the two cases by Mr. Dixon, both common sensation and the sense of taste were annihilated in those parts of the tongue supplied by the fifth pair ; while in one case related by Mr. Noble, and another by Vogt, common sensation was lost in the parts of the tongue supplied by the third branch of the fifth pair, yet the sense of taste remained in these parts; and in a second case related by Mr. Noble, there was loss of taste with maintenance of feeling." In some of these cases the loss of the sense of taste appeared to extend to the base of the tongue; but there was evidence that in these the glosso-pharyngeal nerve was also involved in the paralysis. "We have no proof," continues Dr. Reid, "that in the cases related by Mr. Noble and Vogt, *the whole* of the filaments of the fifth pair sent to the tongue were affected; and in the case of Vogt the derangement of the nerve was only temporary, for the patient recovered the sensation of the part paralysed after the end of six weeks. We believe that these cases, when examined more closely, will rather be regarded as affording arguments in favour of the opinion, that the same nervous filaments do not convey inwards the impressions which excite pain and touch and the impressions which excite taste ; and that different filaments for conveying inwards the impressions that excite these sensations are bound up in the lingual branch of the fifth pair." There is believed to be no case on record, in which the whole of the fifth pair, or of the third branch of it, was found to be diseased after death, and in which, during life, the sense of taste had been retained in the anterior and middle parts of the tongue. The evidence of pathology, therefore, is in favour of that conclusion, as to the participation of the fifth pair with the glosso-pharyngeal in the sense of taste, at which we had arrived on other grounds.

The question still remains, however, as to the *speciality* of the nervous fibres which convey the gustative impressions ; that is, whether they are the common sensory fibres, whose peculiarity of function depends on the nature of the papillary apparatus at their peripheral origin; or whether they are incapable, like the fibres of the olfactive, optic, and auditory nerves, of conveying impressions of the ordinary sensorial kind, being adapted exclusively to receive and transmit the peculiar impressions made by sapid bodies. Now, in favour of the first view, it may be urged, that the conditions of the sense of taste are so nearly allied to those required for the exercise of touch, that the two can scarcely be distinguished on this ground, and that the fifth pair and the glosso-pharyngeal are both nerves of common as well as of gustative sensibility ; neither of which can be affirmed in regard to the three other senses, or of the nerves which minister to them. But, on the other hand, it must be remarked, that these nerves do not seem to be endowed with gustative and common sensibility in equal proportions; for the glosso-pharyngeal, which is decidedly more

* Physiological, Pathological, and Anatomical Researches, p. 268.

susceptible than the lingual to gustative impressions, far less readily excites manifestations of pain when subjected to mechanical irritation. Hence, it would seem not improbable, that there may be in each a mixture of the fibres which minister to the sense of taste with those of tactile sensibility; and that the former may be so far special in their endowments, as to be capable of receiving only the peculiar impressions made by sapid bodies, to which the latter may be insensible. Such a view would seem to be supported by the cases of Vogt and Noble just referred to; and it is in harmony with the views to which we are led from the consideration of the diversities manifested between the sense of heat and cold and that of simple contact. [See Touch.]

Gustative Papillæ.—The tongue is copiously furnished with a papillary structure, bearing a close resemblance to that of the skin, but in many respects more complicated. Referring to the article Tongue for a more particular anatomical description of these papillæ, we have now to inquire into their connexion with the sense of taste. According to the recent investigations of Messrs. Todd and Bowman, the lingual papillæ are either *simple* or *compound;* the former, which do not differ from those of the cutaneous surface in any other obvious character than the nature of their epithelial investment, are scattered over the whole surface of the tongue, in parts where the others do not exist, but they also participate in the formation of the compound papillæ; the latter are of three kinds, the *circumvallate* or *calyciform*, the *fungiform*, and the *conical.*—The *circumvallate* papillæ, which are only eight or ten in number, and are restricted to a small space at the base of the tongue, consist merely of groups of simple papillæ, arranged in a peculiar manner, and separated from those of the adjacent mucous membrane by a circular fissure. Into these simple papillæ it has not yet been found possible to trace any distinct nerve-fibres, though there can be little doubt that it is penetrated by at least the essential part of them.—The *fungiform* papillæ are scattered singly over the surface, chiefly about the sides and apex, and but very sparingly in the middle of the dorsal region, though they are abundant in front of the circumvallate papillæ. These are composed of aggregations of simple papillæ, which rise, however, considerably above the surface, and are covered with an epithelium so thin that they are distinguished by their blood-red colour. Fasciculi of nerve-tubes may be distinctly traced into them; but of the nature of their termination it would be unwise to give a positive statement. Some of the appearances presented by them favour the idea that they form loops at their peripheral extremities; whilst, in other instances, the tubular portion of the fibre, with the white substance of Schwann, seems to terminate somewhat abruptly, whilst the central axis is continued onwards into the substance of the enveloping tissue, in which it loses itself. —The *conical* or *filiform*, which are the most numerous of the compound papillæ, are diffused over the whole surface of the tongue, though most largely and numerously developed in its central part. They consist of clusters of simple papillæ of a peculiarly elongated form, containing tubular nerve-fibres, which may frequently be seen to form distinct loops in their interior; but their chief peculiarity consists in their epithelial investment, which forms about two-thirds of their length, and gives to them their whitish tint. This investment consists of a tuft of long pointed processes, some of which present a near approach in their dense texture to hair; whilst others may be regarded as soft or uncondensed hairs. These processes are sent off from the sides and summits of the secondary papillæ, and are usually inclined backwards, lying buried in the recesses of the mouth. The foregoing description applies, however, only to the conical papillæ of the human tongue; and there is a considerable diversity in their structure in other animals. Thus, in the Ruminants, each conical papilla is terminated by a long, slender, flexible, horny filament, curving backwards; and in the Felines some of them are furnished with a brush-like tuft of slender horny filaments, like those of man*, whilst others are encased by firm horny sheaths, which are prolonged backwards as stiff spines. It is to this arrangement that the peculiar roughness of the tongue of the cat is due; the organ being thus enabled to act as a flexible rasp, whereby the bones which they lick may be effectually cleaned of the smallest particles of flesh that may adhere to them; and a single stroke of the tongue of a lion is said to be capable of abrading the whole thickness of the human skin.

After what has been already said of the conditions essential to the exercise of the sense of taste, there is no occasion to do more than point out the evident fact, that, if some of the papillæ be covered with an epithelial investment so dense as to resemble horn, and offering an effectual barrier to the penetration of fluids, these cannot be supposed to have much participation in the sense, if they possess any. It is obvious that in the Felines the function of the spiny papillæ must be purely mechanical; and it seems probable that the brush-like papillæ which lie among them, in common with those of man, possess simple tactile sensibility, serving to direct those muscular actions of the organ, which so remarkably adapt it to deal with minute particles of food. On the other hand, the thinness of the epithelial investment on the simple papillæ which are scattered over the surface of the tongue, and which form the circumvallate and fungiform papillæ by their aggregation, indicates their special adaptation to receive gustative impressions; and this must be admitted to be more especially the case with the fungiform papillæ, which often

* By Cuvier these filaments are supposed to be the ultimate fasciculi of the fibres of the gustative nerve; but this is certainly an error.

undergo a kind of erection when sapid substances are brought into contact with them. This inference is in complete harmony with the relative acuteness of the senses of taste and touch, in the portions of the surface on which the one or the other class of papillæ is most abundant; thus the sides and back part of the tongue are unquestionably the parts where the gustative sensibility is the greatest, and it is there that the fungiform, circumvallate, and simple papillæ are most thickly set; whilst the apex and central part of the dorsum, over which the tactile sensibility is predominant, is that on which we meet with the largest number of filiform papillæ. Whether there be any difference among the simple isolated papillæ, and among those which are aggregated into the composite bodies that are termed fungiform and circumvallate, we are scarcely in a condition even to form a guess, until it shall have been determined whether the gustative and tactile nerve-fibres are identical or diverse in their endowments. If the former, it will be reasonable to suppose that every papilla through which a gustative impression can be made in virtue of the penetration of sapid matter into its tissue, may also be subservient to the reception of tactile impressions from mechanical stimulation. On the other hand, if it should be proved that the gustative sense depends on a *special* set of fibres, we should still have to inquire whether the same papilla may not contain fibres of both classes, so as to minister to both functions ; or whether some of the papillæ are purely gustative, whilst others are purely tactile.

At present there is no adequate reason to suppose that there is any essential difference of function among the papillæ covered with a soft thin epithelium, whether these be solitary or aggregate. An attempt was made by Horn * to establish some such diversity ; but the results of his experiments would rather lead to the supposition that there is a difference in the gustative sensations excited by the same substance, according as it is applied to different regions of the tongue, than to different papillæ. Thus he found that more than three-fourths of the substances which he applied to the circumvallate papillæ excited a bitter taste, or one in which a bitter was associated with some other flavour, especially an alkaline or saline ; whilst the majority of the substances applied to the filiform papillæ tasted acid, or acid with a mixture of bitter and sweet. But since, as we have seen, mere mechanical stimulation produces different gustative sensations according to the part of the tongue to which it is applied, it is probable that the difference in Horn's results is not to be set down to the account of the papillæ, but rather to that of the nerves by which they are respectively supplied.

Exercise of the Sense.—The simple application of a sapid substance to the gustative surface is usually sufficient to excite the sensation ; and if this application be restricted to one particular spot, we are able to recognise its place more or less distinctly. In this respect, then, the gustative impression resembles the tactile ; for whilst we cannot, by our own consciousness, distinguish the parts of the retina or of the auditory apparatus on which visual or auditory impressions are made, we can make this distinction in regard to the surface which is supplied by the nerves of general sense. This determination is most precise when the impression is made on the parts of the tongue of which the gustative sensibility is most acute ; namely, the apex, sides, and posterior part of the dorsum; being probably aided, however, near the tip, by the acuteness of its tactile sensibility. The impressibility of the middle portion of the dorsum is greatly inferior ; but still, when the gustative sensation has been excited there, it is referred to the spot on which the sapid substance was laid. The contact of sapid substances much more readily excites a gustative sensation, when it is made to press upon the papillæ, or to move over them. Thus there are some substances whose taste is not perceived when they are simply applied to the central part of the dorsum of the tongue, but of whose presence we are at once rendered cognizant by pressing the tongue against the roof of the mouth. The full flavour of a sapid substance, again, is more readily perceived when it is rubbed on any part of the tongue, than when it is simply brought in contact with it or pressed against it. Even when liquids are taken into the mouth, their taste is most completely discriminated by causing them to move over the gustative surface: thus the "wine-taster" takes a small quantity of the liquor into his mouth, carries it rapidly over every part of its lining membrane, and then ejects it. It is not improbable that this exaltation of the usual effects is simply due to mechanica causes ; the sapid particles being brought by the pressure or movement into more rapid and complete operation on the nerve-fibres, than they would be if simply placed in contact with the papillæ.

As in the case of the other senses, so do we find with regard to that of taste, that continual attention to its indications greatly increases its acuteness. Thus the "tasters" of wine, tea, &c., acquire a power of discrimination which is truly wonderful to those who have not exercised themselves in the same manner. Thus we have been informed that the "taster" to one of the extensive cellars of sherry wines at Cadiz or Seville has not the least difficulty in distinguishing the butt from which a given sample may have been drawn, although the number of different varieties of the same kind of wine under his keeping may not be less than five hundred. So we are informed by Dr. Kitchener that many London epicures are capable of saying in what precise reach of the Thames the salmon on the table has been caught; and the Parisian *gourmet* is said to be able to distin-

* Ueber den Geschmacksinn des Menschen. Heidelberg, 1825.

guish by the taste, whether the birds on which he is dining are domesticated or wild, male or female, or to give an exact determination of the spices, &c., that are combined in a particular sauce.

On the other hand, the power of distinguishing sapors is for a time suspended, when several substances of very decided but different tastes are taken into the mouth in quick succession: thus, if sweet, sour, salt, or bitter substances be applied to the tongue, or if different kinds of wine be taken, one after another, the sense is so much blunted after a short time, as to impair or destroy the power of discrimination between them until after an interval of rest. So, again, when two substances of very different flavours are mingled together, the stronger will frequently mask the presence of the weaker: thus we often find it advantageous, in prescribing nauseous medicines, to combine with them aromatics, whose stronger impression shall take possession (so to speak) of the sense for a time; and the object may be still more completely attained by giving the aromatic a moment or two previously, instead of simultaneously with the disagreeable substance.

The influence of habit in blunting the sensibility to particular tastes, is as remarkable as it is in the case of other sensations. Still more extraordinary, however, is the degree in which the taste may be educated to approve savours which are in the first instance most disgusting. "Thus," says Dr. Dunglison*, "the Roman *liquamen* or *garum*, the most celebrated sauce of antiquity, was prepared from the half-putrid intestines of fish: and one of the varieties of the Οπος σιλφιου, or *laserpitium*, is supposed to have been the assafœtida. Even at this time, certain of the Orientals are fond of the flavour of this nauseous substance. Putrid meat is the delight of some nations; and a rotten egg, especially if accompanied with the chick, is highly esteemed by the Siamese. In civilised countries, we find game, in a putrescent state, eaten as a luxury; this, to those unaccustomed to it, requires a true education. The same may be said of the pickled olive, and of several cheeses; the *fromage de Gruyère*, for example, so much esteemed by the inhabitants of continental Europe." Very extraordinary appetencies for particular flavours are sometimes morbidly developed; as in the case of chlorotic girls, pregnant women, and insane patients. The latter will sometimes even devour their own excrement.

Independently of the changes produced by the education of the taste, we find great alterations in the likes and dislikes connected with it, taking place in accordance with the development of the body, or with other changes in its physiological conditions. Thus to the infant there is obviously nothing so agreeable as milk; in more advanced childhood there is almost invariably a fondness for sweets; whilst after adult age this is usually in a great degree superseded by a preference for other savours. It sometimes happens that articles of diet which were peculiarly agreeable to us in childhood, become positively disgusting to us in later life; whilst, on the contrary, many things to which we feel a strong distaste in childhood, are relished when we come to be men, and this by a spontaneous change in our own appetencies. We fully believe with Wagner that these alterations are in some way connected with the physical condition of the nutritive functions; for we have other examples in which this connexion is very evident. Thus, we may continually remark that articles of food for which we have the keenest relish when we commence a meal with a good appetite, become positively distasteful when we have already satisfied it. Again, we have known persons who have a positive repugnance to fatty or oleaginous matters of almost any description, so long as they reside in temperate climates, but who eat them with avidity when exposed to the severe cold of the arctic winter. And even in our own country we may frequently remark that the taste for such articles varies with the temperature; a cup of sweet oleaginous cocoa, which would be almost loathed on a hot summer day, being very palatable on a cold winter night; whilst ascescent drinks, such as would be greatly relished in the former season, are altogether discarded in the latter, except when a heated atmosphere brings back the physical condition of the system which renders them palatable.

So, again, we often observe in illness that an alteration in the physical conditions of the system so far affects the sense of taste, as to produce a great alteration in the usual appetencies. These alterations may probably be due in some instances to the depravation of the buccal secretions, so that the gustative papillæ are constantly surrounded with a substance possessing a certain taste of its own, which of course affects their impressibility by other savours. But there can be little doubt that they are more commonly occasioned by alterations in the condition of the gustative apparatus itself, which becomes the exponent (so to speak) of the wants of the system, and which may be trusted, to a very considerable extent, as indicating what is really most desirable for it. Thus Dr. Holland remarks*: — "In the majority of instances of actual illness, provided the real feelings of the patient can be safely ascertained, his desires as to food and drink may be safely complied with. But undoubtedly much care is needful that we be not deceived as to the state of the appetites by what is merely habit or wrong impression on the part of the patient, or the effect of the solicitation of others. This class of sensations is more nurtured out of the course of nature than are those which relate to the temperature of the body. The mind becomes much more deeply engaged with them; and though in acute illness they are generally submitted again to the natural law, there are many lesser cases where

* Human Physiology, vol. i. p. 116.

* Medical Notes and Reflections, p. 85.

enough remains of the leaven of habit to render every precaution needful. With such precautions, however, which every physician who can take schooling from experience will employ, the stomach of the patient becomes a valuable guide; whether it dictate abstinence from a recurrence to food; whether much or little in quantity; whether what is solid or liquid; whether much drink or little; whether things warm or cold; whether sweet, acid, or saline; whether bland or stimulating to the taste." Further, Dr. Holland remarks: "It is not wholly paradoxical to say that we are authorised to give greatest heed to the stomach when it suggests some seeming extravagance of diet. It may be that this is a mere depravation of the sense of taste; but frequently it expresses an actual need of the stomach either in aid of its own functions or indirectly (under the mysterious law just referred to) for the effecting of changes in the whole mass of blood. It is a good practical rule in such cases to withhold assent till we find after a certain lapse of time that the same desire continues or strongly recurs; in which case it may generally be taken as the index of the fitness of the thing desired for the actual state of the organs. In the early stage of recovery from long gastric fevers, I recollect many curious instances of such contrariety to all rule being acquiesced in, with manifest good to the patient. Dietetics must become a much more exact branch of knowledge, before we can be justified in opposing its maxims to the natural and repeated suggestions of the stomach, in the state either of health or disease." In regard to the use of wine in fever, it is universally admitted by practical physicians that very important indications may frequently be drawn from the appetency or dislike manifested towards it by the patient; this being often exhibited when there is an almost entire obtuseness of the mind in regard to all other external impressions. In such circumstances these dormant instincts seem to manifest themselves, which are kept under by the intelligence in the normal condition; instincts akin to those which guide the lower animals in their choice of food. There is probably not a plant, however poisonous to most, which has not one or more species of animal specially adapted to derive from it wholesome nutriment, and which is obviously drawn to it by its odour or savour; whilst the most omnivorous feeders, such as the monkey, are usually restrained by dislikes, excited through these same senses, from touching fruits which would be noxious to them.

It cannot be doubted that, in all persons of ordinary aptitude for the discrimination of flavours, there are certain natural harmonies and discords among these, as among colours and sounds; so that particular substances of very different flavours taste agreeably in combination, whilst others are mutually repugnant. Thus every body likes sugar in combination with the acid of fruits; and the sugar is popularly believed to neutralise the acid, which (as we need scarcely say) is not at all the case. On the other hand, sugar and oysters are said to form one of the most nauseous combinations possible. So, again, the flavour of many wines is improved by being tasted simultaneously with cheese, whilst it is injured by fruits.—The art of cookery is founded upon a knowledge of these facts, which have not yet perhaps received from the scientific physiologist the systematic attention they deserve. Attempts have been made by Linnæus, Boerhaave, and others, to form a classification of savours; but no such classification has come into general use, although there are certain savours which all agree to consider *primary;* such as the *aromatic*, the *sweet*, the *acid*, the *bitter*, the *saline*, the *astringent*, and the *pungent*. By the first of these the sense of taste is connected with that of smell; by the last two with that of touch.

The impressions made upon the sense of taste seem to remain longer after the withdrawal of the body that excited them, than those which are received through most of our other senses. This is not surprising, when it is considered that particles of the sapid substance, which have once penetrated the papillæ, may linger there in contact with the sentient extremities of the nerves, for some little time after they have passed away from the external surface. In many cases, however, the substance leaves an *after-taste* which is different from that which it first excited. It is difficult to say how much of this may be due to the difference of the impression which is made upon the sensory papillæ at the front of the tongue and upon those at its base, and also to the admixture of the olfactive sense, which will be most actively called into play as the sapid body is passing the fauces; and how much to the exhaustion of the nerves consequent upon their previous stimulation, so that the after-taste is *complementary* to that first received. It certainly appears to confirm the former explanation, that the after-taste is generally of that bitterish character which we have seen to be produced by the mere mechanical stimulation of the papillæ at the base of the tongue. On the other hand, the fact that *tannin*, one of the bitterest substances known, has a sweetish after-taste, seems to favour the latter view. Probably both causes may participate in the production of the result.

It is not very common to find the sense of taste excited in a purely *subjective* manner; since many of the tastes which are experienced in disease are probably due, as already remarked, to the depravation of the buccal secretions. Nevertheless, we occasionally meet with instances in which some peculiar gustative sensation, usually of a disagreeable nature, is constantly experienced without being traceable to any such cause; and in which, therefore, we must seek for its occasion in some disordered functional condition of the sensorium.

The *purpose* of the sense of taste is obviously to serve as the guide and attraction towards wholesome food, and to afford pleasure in the reception of it, whilst it deters from the use of such as would be deleterious. This is more obvious in the lower animals than it is in man, who is frequently led by habit and fashion to a preference for substances which are high-flavoured over those which are most wholesome, and who is still more frequently induced to gratify his gustative sense by the reception of an amount of food which appetite alone would not incite him to take in. Of the pernicious results of such excess, this is not the place to speak.

The only ulterior purposes which the sense of taste appears to perform in the economy, are to aid in exciting the flow of saliva, and in certain cases to excite the act of vomiting. Although the secretion of saliva is greatly affected by other causes,—as, for example, by the movement of the jaws, tongue, &c.,—yet it is much influenced by the sapid qualities of the food introduced into the mouth, being greatly increased by the taste of savoury food. It is also augmented by the sight or odour of such food; but it is probable that the latter sensations influence it not so much directly as indirectly, namely, through the *ideas* which they call up, for the idea alone, if called up with sufficient vividness, is sufficient to make "the mouth water." The sense of nausea, as already remarked, seems intermediate between taste and touch; but it is connected most closely with the former. We experience more or less of difficulty in swallowing all substances whose taste is peculiarly repugnant to us, and we find ourselves compelled to regurgitate them when the impression becomes of a certain intensity. This is one of the automatic actions in which it appears requisite that a *sensation*, not a mere impression, should participate.

(*William B. Carpenter.*)

TEETH.—Comparative Anatomy. (Sing. *a tooth; Tunth,* Teut.; *Dens,* Lat.; *Dente,* Ital.; *Dent,* Fr.; *Tand,* Dan.; *Tain,* Old English; *Zahn,* Germ.; *Dant,* Welsh; *Dend,* Erse; οδους-οδοντος, Gr.; *Dantis,* Lithuanic; *Dantas,* Sanscrit.*) A tooth is a hard body attached to the mouth or commencement of the alimentary canal, always exposed, save where its development is permanently arrested, as in the rudimental tusk of the Narwhal; commonly calcified, the exceptions being few, *e. g.,* the horny teeth of the Lamprey and Platypus. Teeth vary not only in their tissue, but still more in number, size, form, structure, position, and mode of attachment, in different animals: they are principally adapted for seizing, tearing, dividing, pounding, or grinding the food; in some they are modified to serve as weapons of offence and defence; in others as aids in locomotion, means of anchorage, instruments for uprooting or cutting down trees, or for transport and working of building materials; they are characteristic of age and sex; and in man they have secondary relations subservient to beauty and to speech.

Teeth are always most intimately related to the food and habits of the animal, and are therefore highly interesting to the physiologist: they form for the same reason most important guides to the naturalist in the classification of animals; and their value, as zoological characters, is enhanced by the facility with which, from their position, they can be examined in living or recent animals; whilst the durability of their tissues renders them not less available to the palæontologist in the determination of the nature and affinities of extinct species, of whose organisation they are often the sole remains discoverable in the deposits of former periods of the earth's history.

Although there are many analogous structures in the inverterbrate classes, true calcified teeth are peculiar to the Vertebrata, and may be defined as bodies primarily, if not permanently, distinct from the skeleton, consisting of a cellular and tubular basis of animal matter containing earthy particles, a fluid, and a vascular pulp.

In general, the earth is present in such quantity as to render the tooth harder than bone, in which case the animal basis is gelatinous, as in other hard parts where a great proportion of earth is combined with animal matter. In a very few instances among the vertebrate animals, the hardening material exists in a much smaller proportion, and the animal basis is albuminous; the teeth here agree, in both chemical and physical qualities, with horn.

True teeth consist commonly of two or more tissues, characterised by the proportions of their earthy and animal constituents, and by the size, form, and direction of the cavities in the animal basis which contain the earth, the fluid, or the vascular pulp.

The tissue which forms the body of the tooth is called "dentine," (*Dentinum,* Lat.; *Zahnbein, Zahnsubstanz,* Germ.; *l'Ivoire**, Fr.)

The tissue which forms the outer crust of the tooth is called "cement" (*cæmentum, crusta petrosa,* Lat.).

* These synonyms are cited as illustrative of the coincidence in one of the primary words of a natural class of languages that prevails from the East Indies, through the west of Asia and across Europe, and as indicative of the unity of stock of the great Indo-European family of mankind.

* The learned author of the article "Sécrétions," in the "Dictionnaire Universel d'Histoire Naturelle," 8vo, 1848, adopts the term "Dentine" in preference to Cuvier's name "ivoire," and after defining its properties, observes, "Sur ces divers rapports, le mot *dentine,* par lequel M. R. Owen les désigne, me paraît très heureux." The term "ivory" unavoidably recalls the idea of the peculiar modification of "dentine," which characterises the tusks of the elephant, mammoth, and mastodon; but, besides this objection to its more general application, the word is used in a still wider sense in the "Leçons d'Anatomie Comparée:" "Les unes (dents), en effet, ont la partie enfoncée dans l'alvéole dénuée d'émail; cette partie, ou la racine, ne se compose généralement que de l'*ivoire* intérieure, recouvert très rarement d'*ivoire* extérieure (les dents de cachalot);" tom. iv. Ed. posth. 1836, p. 200. The example cited of the tissue here denominated "ivoire extérieure" is the "cement." See my "Odontography," p. 355, pl. 89.

The third tissue, when present, is situated between the dentine and cement, and is called "enamel" (*encaustum*, *adamas*, Lat.).

"*Dentine*" consists of an organised animal basis disposed in the form of extremely minute tubes and cells, and of earthy particles: these particles have a twofold arrangement, being either blended with the animal matter of the interspaces and parietes of the tubes and cells, or contained in a minutely granular state in their cavities. The density of the dentine arises principally from the proportion of earth in the first of these states of combination, the tubes and cells contain, besides the granular earth, a colourless fluid, probably transuded "plasma" or "liquor sanguinis," and thus relate not only to the mechanical conditions of the tooth, but to the vitality and nutrition of the dentine.

This typical structure of dentine is well illustrated in the article Tooth: such "true dentine" has no canals large enough to admit capillary vessels with the red particles of blood, and it has been therefore called "unvascular dentine."

The simplest modification of dentine is that in which capillary tracts of the primitive vascular pulp remain uncalcified, and permanently carry red blood into the substance of the tissue. These so-called "medullary canals" or "vascular canals" present various dispositions in the dentine which they modify, and which I have proposed to call "vaso-dentine." It is often combined with true dentine in the same tooth; *e.g.* in the scalpriform incisors of certain Rodents*, the tusks of the Elephant†, the molars of the extinct Iguanodon.‡

A third modification of the fundamental tissue of the tooth is where the cellular basis of the dentine is arranged in concentric layers around the vascular canals, and contains "radiated cells" like those of the osseous tissue: it is called "osteo-dentine." The transition from dentine to vaso-dentine, and from this to osteo-dentine, is gradual, and the resemblance of osteo-dentine to true bone is very close.

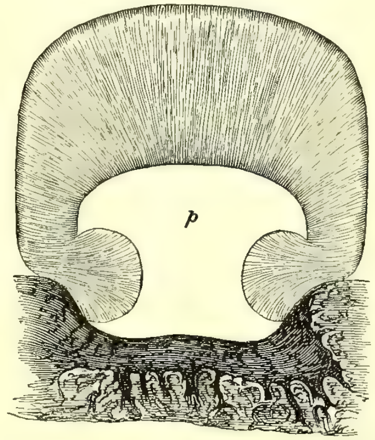
"*Cement*" always closely corresponds in texture with the osseous tissue of the same animal; and wherever it occurs of sufficient thickness, as upon the teeth of the horse, sloth, or ruminant, it is also traversed, like bone, by vascular canals. In reptiles and mammals, in which the animal basis of the bones of the skeleton is excavated by minute radiated cells, forming with their contents the "corpuscles of Purkinje," these are likewise present, of similar size and form, in the "cement," and are its chief characteristic as a constituent of the tooth. The hardening material of the cement is partly segregated and combined with the parietes of the radiated cells and canals, and is partly contained in disgregated granules in the cells, which are thus rendered white and opaque, viewed by reflected light. The relative density of the dentine and cement varies according to the proportion of the earthy material, and chiefly of that part which is combined with the animal matter in the walls of the cavities, as compared with the size and number of the cavities themselves. In the complex grinders of the elephant, the masked boar, and the capybara, the cement, which forms nearly half the mass of the tooth, wears down sooner than the dentine.

The "*enamel*" is the hardest constituent of a tooth, and, consequently, the hardest of animal tissues; but it consists, like the other dental substances, of earthy matter arranged by organic forces in an animal matrix. Here, however, the earth is mainly contained in the canals of the animal membrane; and, in mammals and reptiles, completely fills those canals, which are comparatively wide, whilst their parietes are of extreme tenuity. The hardening salts of the enamel are not only present in far greater proportion than in the other dental tissues; but, in some animals, are peculiarly distinguished by the presence of fluate of lime.

The following are characteristic examples of the above-defined tissues, and their different combinations, in different teeth.

The examples are extremely few, and, as far as I know, are peculiar to the class *Pisces*, of calcified teeth which consist of a single tissue, and this is always a modification of dentine. The large pharyngeal teeth of the Wrasse (*Labrus*) consist of a very hard kind of unvascular dentine. *Fig.* 544. shows a vertical section of one of these teeth, supported upon the very vascular osseous tissue of the pharyngeal bone: *p* is the pulp cavity.

Fig. 544.



Section of pharyngeal tooth of Labrus, magnified. (*Owen's Odontography.*)

The next stage of complexity is where a portion of the dentine is modified by vascular canals. Teeth, thus composed of dentine and vaso-dentine, are very common in fishes. The hard dentine is always external, and holds the place, and performs the office, of enamel in the teeth of higher animals; but it is only analogous to enamel, not the same

* Odontography, 4to, p. 405.
† Ib. p. 643.
‡ Ib. p. 251.

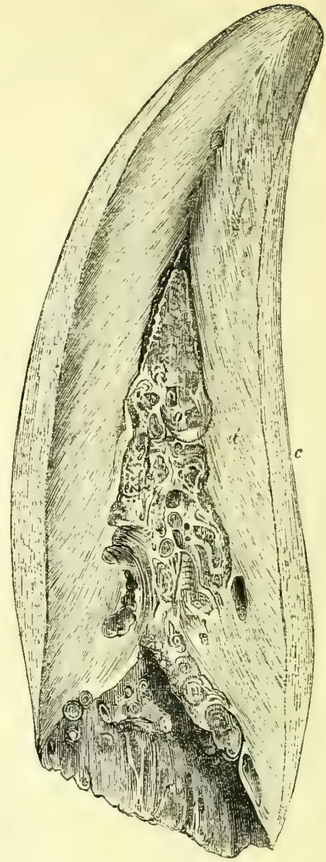
tissue.* *Fig.* 545. illustrates this structure in a longitudinal section of a tooth of a shark of

Fig. 545.

Section of tooth of Lamna, magnified.
(*Owen's Odontography.*)

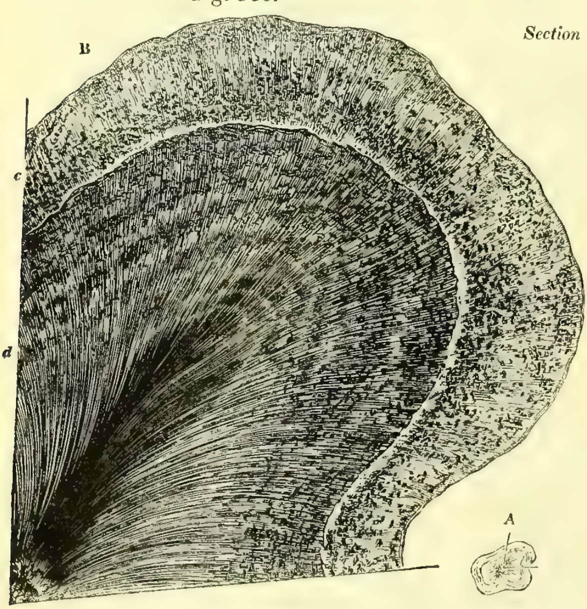
the genus *Lamna:* *v* is the vaso-dentine; *d* the hard dentine; the earthy constituent so

Fig. 547.



Section of tooth of Cachalot (Physeter).

Fig. 546.



Section of tooth of Dugong (Halicore), magnified.

predominates that the tissue takes a polish like enamel, for which it has commonly been mistaken in the teeth of fishes: I have called it "vitro-dentine."

The molars of the Dugong are examples of teeth composed of dentine and cement, the latter tissue forming a thick external layer. *Fig.* 546. A. is a transverse section of the crown of the second molar, natural size; and B. a magnified view of a portion of the section; *d* the dentine. remarkable for the number of minute calcigerous cells at its periphery; and *c* the cement.

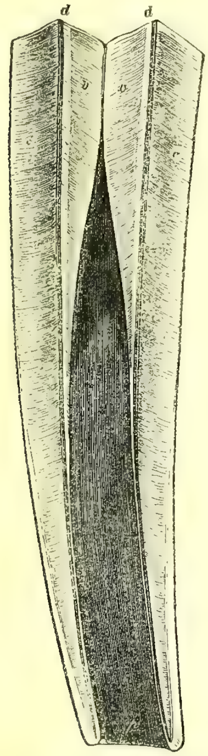
In the great teeth of the lower jaw of the Cachalot, the pulp-cavity of the growing tooth becomes filled up by osteo-dentine, the result of a modified calcification of the dentinal pulp; and the full-grown tooth presents three tissues, as shown

* Odontography, pp. 17, 37.

in *fig.* 547., in which *c* is the thick external cement, *d* the hard dentine, and *o* the osteo-dentine; sometimes developed in loose stalactitic-shaped nodules.

In the teeth of the Sloth, and its great extinct congener, the Megatherium, the hard dentine is reduced to a thin layer, and the chief bulk of the tooth is made up of a central body of vaso-dentine, and a thick external crust of cement. *Fig.* 548. represents a

Fig. 548.



Section of tooth of Megatherium.

longitudinal section of a lower molar of the Megatherium, of half the natural size: *v* is the vaso-dentine, *d* is the hard dentine, and *c* is the cement; *p* is the base of the wide persistent pulp-cavity.

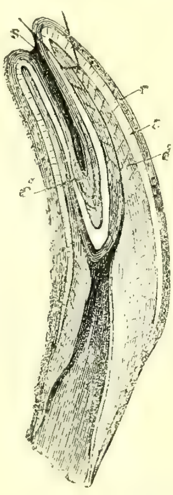
The hard dentine is, of course, the firmest tissue of a tooth so composed, and forms the crest of the transverse ridges of the grinding surface, like the enamel plates in the elephant's grinder. It has, consequently, been described to be enamel*, but its relation to that tissue is only one of analogy or function.

The human teeth, and those of the carnivorous mammals, appear at first sight to be composed of dentine and enamel only, as they were described to be by the Cuviers †, who called them, therefore, simple teeth; but their crowns are originally, and their fangs are always, covered by a thin coat of cement. There is also commonly a small central tract of osteo-dentine in old teeth.

In *fig.* 7, pl. 122, of my Odontography is given a longitudinal section of a human molar tooth, in which *d* is the dentine, *e* the enamel, and *c* the cement.

The teeth, called by Cuvier compound or complex in Mammalia, differ, as regards their composition, from the preceding, only by the different proportion and disposition of the constituent tissues. *Fig.* 549. is a longitudinal section of the incisor of a horse; *d* is the dentine, *e* the enamel, and *c* the cement; *c′* is the layer of cement reflected into the deep central depression of the crown; and *s* is the coloured mass of tartar and particles of food which fills up that cavity, forming the "mark" of the horse-dealer. The characteristic structure of the three tissues is shown in the magnified part of the section, *fig.* 550.

Fig. 549.



Section of incisor of a Horse (Equus).

A very complex tooth may be formed out of two tissues by the way in which these may be interblended, as the result of an original complex disposition of the constituents of the dental matrix.

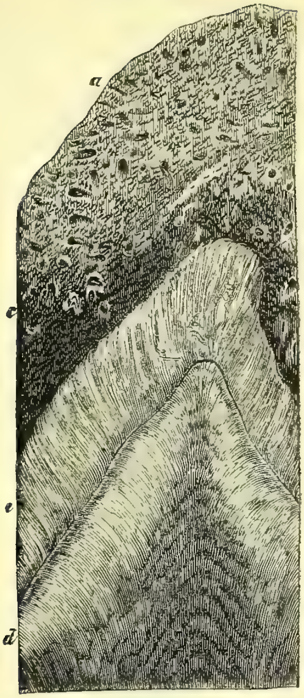
Certain fishes, and a singular family of gigantic extinct Batrachians, which I have called "Labyrinthodonts,"* exhibit, as the name implies, a remarkable instance of this kind of complexity. *Fig.* 551. is a view of a canine tooth of the *Labyrinthodon salamandroïdes*, of the natural size; and *fig.* 552. is a slightly magnified view of a transverse section across the part of the crown marked *a*. At first view, the tooth appears to be of the simple conical kind, with the exterior surface merely striated longitudinally, but every streak is a fissure into which the very thin external layer of cement (*c*) is reflected into the body of

* Cuvier, Ossemens Fossiles, 4to, t. v., pt. 1., p. 172.; and Clift, Transactions of the Geological Society, 1835, p. 438.

† F. Cuvier, Dents de Mammifères, p. 1. 8vo, 1825; G. Cuvier, Leçons d'Anat. Comp. iv. (1836), p. 199.

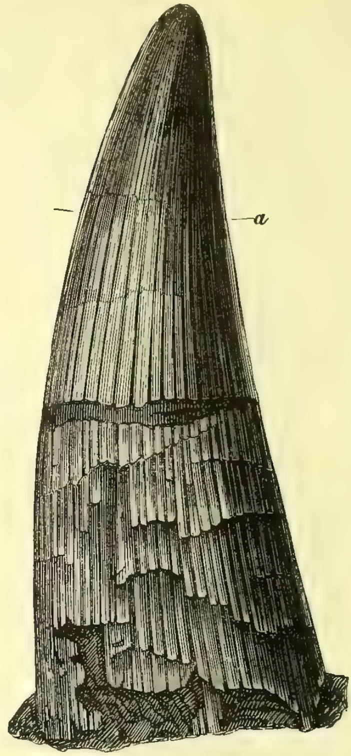
* Proceedings of the Geological Society, Jan. 20, 1841, p. 257.

Fig. 550.



Magnified portion of section of incisor of Horse ; *c* cement, *e* enamel, *d* dentine.

Fig. 551.

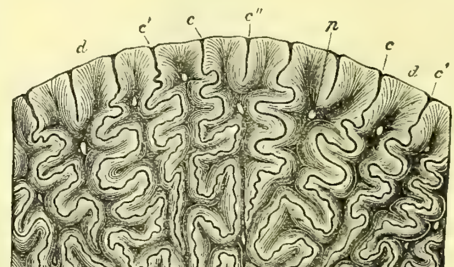


Tooth of a Labyrinthodon, natural size.

the tooth, following the sinuous wavings of the lobes of dentine (*d*), which diverge from the central pulp-cavity, *a*.

The inflected fold of cement *c* runs straight for about half a line, and then becomes wavy, the waves rapidly increasing in breadth as they recede from the periphery of the tooth ; the first two, three, or four undulations are simple ; then their contour itself becomes broken by smaller or secondary waves ; these become stronger as the fold approaches the centre of the tooth, when it increases in thickness, and finally terminates by a slight dilatation or loop close to the pulp-cavity, from which the free margin of the inflected fold of cement is separated by an extremely thin layer of dentine. The number of the inflected converging folds of dentine is about fifty at the middle of the crown of the tooth figured, but is greater at the base. All the inflected folds of cement at the base of the tooth have the same complicated disposition with increased extent; but, as they approach their termination towards the upper part of the tooth, they also gradually diminish in breadth, and consequently penetrate to a less distance into the substance of the tooth. Hence, in such a section as is delineated (*fig.* 552.), it will be observed that some of the convoluted folds, as those marked *c c*, extend near to the centre of the tooth; others, as those marked *c′*, reach only about half-way to the centre; and those folds, *c″*, which, to use a geological expression, are "cropping out," penetrate to a very short distance into the dentine, and resemble, in their extent and

Fig. 552.



Transverse section of tooth of Labyrinthodon. (*Magnified.*)

simplicity, the converging folds of cement in the fangs of the tooth of the Ichthyosaurus.

The disposition of the dentine is still more complicated than that of the cement. It consists of a slender, central, conical column, excavated by a conical pulp-cavity for a certain distance from the base of the tooth; and this column sends radiating outwards, from its circumference, a series of vertical plates, which divide into two once or twice before they terminate at the periphery of the tooth.

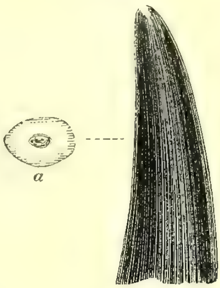
Each of these diverging and dichotomising plates gives off throughout its course smaller processes, which stand at right angles, or nearly so, to the main plate; they are generally opposite, but sometimes alternate; many of the secondary plates or processes, which are given off near the centre of the tooth, also divide into two before they terminate; and their contour is seen, in the transverse section, to partake of all the undulations of the folds of cement which invest and divide the dentinal plates and processes from each other.

The dental pulp-cavity is reduced to a mere line about the upper third of the tooth, but throughout its whole extent fissures radiate from it, corresponding in number with the radiating plates of dentine. Each fissure is continued along the middle of each plate, dividing where this divides, and extending along the middle of each bifurcation and process to within a short distance of the line of cement. The pulp-fissure commonly dilates into a canal at the origin of the lateral processes of the radiating plates, before it divides to accompany and penetrate those processes.

The main fissures or radiations of the pulp-cavity extend to within a line or half a line of the periphery of the tooth, and suddenly dilate at their terminations into spaces, which, in transverse section, are subcircular, oval, or pyriform, *p*: the branches of the radiating lines, which are continued into the lateral secondary plates or processes of the dentinal lamellæ, likewise dilate into similar, and generally smaller spaces. All these spaces, or canals, in the living tooth, must have been occupied by corresponding processes of the vascular pulp: they constitute so many centres of radiation of the fine calcigerous tubes, which, with their uniting clear substance, constitute the dentine.*

An analogous complexity is produced by numerous fissures radiating from a central mass of vaso-dentine, which more or less fills up the pulp-cavity of the seemingly simple conical teeth of the extinct family of fishes which I have called "Dendrodonts."† *Fig.* 553. is one of these fossil teeth, of the natural size; *a* a transverse section; and *fig.* 554 a reduced view of a portion of the same section, enlarged twenty diameters.

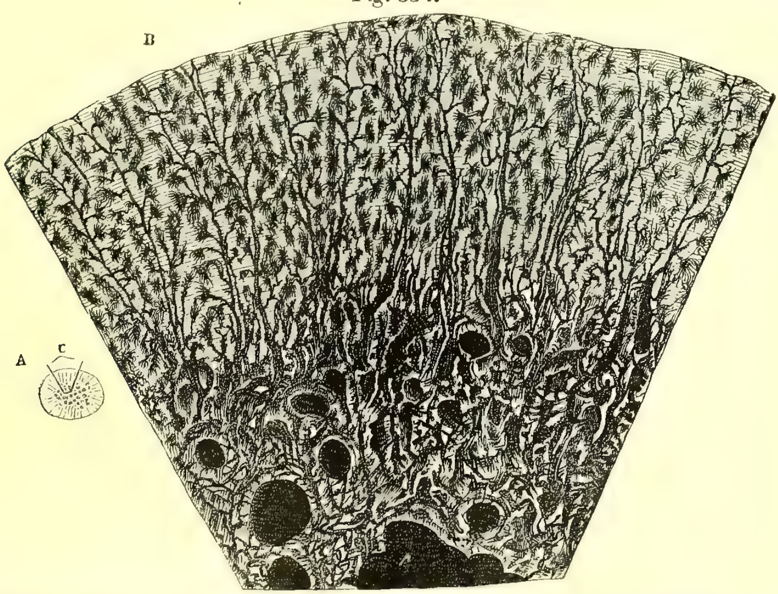
Fig. 553.



Tooth of a Dendrodus, natural size.

Thus magnified, a central pulp-cavity, of relatively small size, and of an irregular lobulated form, is discerned, a portion of which

Fig. 554.



Transverse section of tooth of Dendrodus. A, natural size; *B,* the portion *c*, of *A*, magnified 20 diameters.

* Odontography, pp. 195—217, pl. 64 A, 64 B.
† Ib. p. 171.

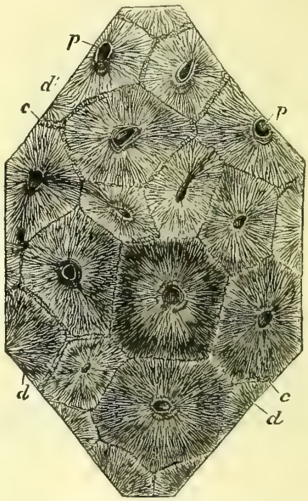
is shown at p; this is immediately surrounded by the transverse sections of large cylindrical medullary, or pulp-canals of different sizes; and, beyond these, there are smaller and more numerous medullary canals, which are processes of the central pulp-cavity. In the transverse section these processes are seen to be connected together by a net-work of smaller medullary canals belonging to a coarse osseous texture into which the pulp has been converted, and this structure occupies the middle half of the section. All the medullary canals were filled by the opaque matrix. From the circumference of the central net-work, straight medullary fissures radiate at pretty regular intervals to the periphery of the tooth: most of these canals divide once, rarely twice, in their course; the division taking place sometimes at their origin, in others at different distances from their terminations, and the branches diverge slightly as they proceed. Each of the above medullary fissures is continued from a short process of the central structure, which is connected by a concave line with the adjoining process, so that the whole periphery of the transverse section of the central coarse reticulo-medullary body of the tooth presents a crenate outline. From each ray and its primary dichotomous divisions, short branches are sent off at brief intervals, generally at right angles with the trunk, or slightly inclined towards the periphery of the tooth. These subdivide into a few short ramifications, like the branches of a shrub, and terminate in irregular and somewhat angular dilatations, simulating leaves, but which resolve themselves into radiating fasciculi of calcigerous tubes. There are from fifteen to twenty-five or thirty-six of these short and small lateral branches on each side of the medullary rays.

A third kind of complication is produced by an aggregation of many simple teeth into a single mass.

The examples of these truly compound teeth* are most common in the class of Fishes, but the illustration here selected is from the Mammalian class. Each tooth of the Cape Ant-eater (*Orycteropus*) presents a simple form, is deeply set in the jaw, but without dividing into fangs; its broad and flat base is porous, like the section of a common cane. The canals to which these pores lead contain processes of a vascular pulp, and are the centres of radiation of as many independent series of dentinal tubules. Each tooth, in fact, consists of a congeries of long and slender prismatic denticles of dentine, which are cemented together by their ossified capsules, the columnar denticles slightly decreasing in diameter and occasionally bifurcating as they approach the grinding surface of the tooth.

A figure of a longitudinal section of the molar teeth is given in Pl. 76, *fig.* 10. of my "Odontography," and a magnified view of a similar section in Pl. 77.; *fig.* 555. gives a magnified view of a portion of the transverse

Fig. 555.



Part of transverse section of the tooth of the Orycteropus. (Magnified.)

section of the fourth molar, showing *c* the cement; *d* the dentine; *p* the pulp-cavity of the denticles; and *d'* a section of one of the denticles just beyond its bifurcation.

The pectinated incisors of the flying Lemur of the Indian Islands (*Galeopithecus*) are examples of teeth, the crowns of which are composed of denticles consisting of hard dentine, with a covering of true enamel. The layer of cement over this is too thin to show its characteristic structure, and does not fill up the intervals of the denticles, which stand out as free processes from the base of the crown. Tubular prolongations of the pulp-cavity are continued up the centre of each denticle.

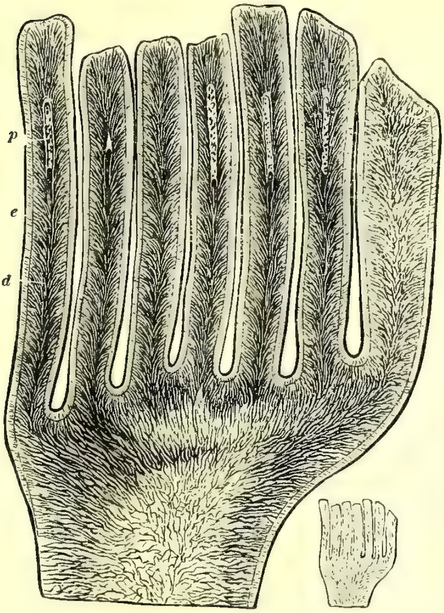
Fig. 556. exhibits a longitudinal section, magnified, of this kind of compound tooth; *d* is the dentine; *e* the enamel; *p* the pulp-cavity. The originally detached summits of the crown of the human incisor are homologous with these columnar processes, or denticles of the incisor of the *Galeopithecus*.

In the compound molars of the great African wart-hogs (*Phacochœrus*) the columnar denticles are in three rows, and their interspaces are filled up by cement: each denticle consists of a slender column of hard dentine inclosed in a thick sheet of enamel, the whole being bound together by the cement; and the

* In the "Leçons d'Anatomie Comparée" of Cuvier, the teeth, in which folds of enamel and cement penetrate the entire substance of the crown, are called "compound:" "Nous appellons 'dent composée' celle dont les différentes substances forment des replis tellement profonds, que dans quelque sens qu'on coupe la dent, on coupe plusieurs fois chacune des substances qui la composent: telles sont les dents molaires de l'*Éléphant*." The teeth of the "Labyrinthodonts" would come under this definition more truly than those of the elephant, although they differ from them in having no enamel; for a molar of an elephant might be bisected, vertically and transversely, without cutting the tissues across more than once.

denticles, as in the *Galeopithecus*, blending together into a common base in the fully-developed tooth.

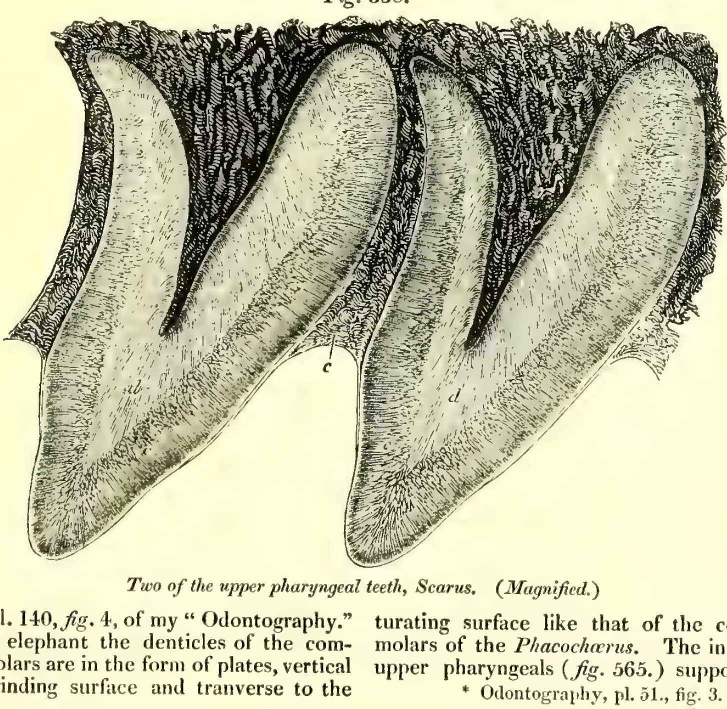
Fig. 556.



Section of lower incisor of Galeopithecus (Magnified.)

A figure is given of the grinding surface of the third true molar of the *Phacochærus Pal-*

Fig. 558.

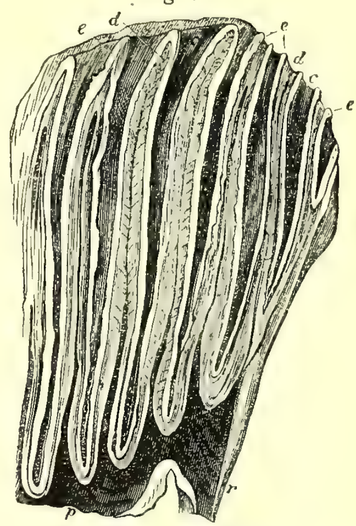


Two of the upper pharyngeal teeth, Scarus. (Magnified.)

lasii, in Pl. 140, *fig*. 4, of my " Odontography."

In the elephant the denticles of the compound molars are in the form of plates, vertical to the grinding surface and tranverse to the long diameter of the tooth. When the tooth is bisected vertically and lengthwise, the three substances, *d* dentine, *e* enamel, and *c* cement,

Fig. 557.



Section of molar of Elephant.

are seen interblended as in *fig*. 557., in which *p* is the common pulp-cavity, and *r* one of the roots of this complex tooth.

A still more complex grinding apparatus is found in certain fishes. The lower pharyngeal bone of the parrot-fish (*Scarus**), for example, supports a dental plate with a triturating surface like that of the compound molars of the *Phacochærus*. The interlocked upper pharyngeals (*fig*. 565.) support dental

* Odontography, pl. 51., fig. 3.

masses with a grinding surface more like that of the compound molars of the elephant.

When a vertical and longitudinal section is made of one of these upper pharyngeal compound teeth, each denticle is seen to be composed, as in *fig.* 558., of a body of very hard and unvascular dentine *d*, with a thick sheath of enamel *e*, the denticles being united together by the cement *c*, and supported and further united together, and to the pharyngeal bone, by a basal mass of vascular osteo-dentine.

Such are some of the prominent features of a field of observation which comparative anatomy opens out to our view; — such the varied nature, and such the gradation of complexity of the dental tissues, which, up to December 1839*, continued, notwithstanding successive approximations to the truth, to be described in systematic works as a "phaneros," or "a dead part or product exhaled from the surface of a formative bulb!" The truth may be slowly but is surely established, subject to the usual attempts to mask or detract from the merit of the discovery. By no systematic authors has the hypothesis of the formation of dentine by transudation or secretion been more frequently or more explicitly enunciated than by the Cuviers. Baron Cuvier repeats, in both editions of his elaborate work — the "Ossemens Fossiles" — "C'est dans ce vide conçevable que se déposeront les matières qui doivent former la dent, savoir: la substance vulgairement appelée *osseuse*, qui sera transudée par des productions gelatineuses venant du fond de la capsule, et l'émail qui sera déposé par les cloisons membraneuses," t. ii. p. 61., ed. 1812.; t. i. p. 33., ed. 1821. See, also, M. F. Cuvier, "Dents de Mammifères," 8vo, 1825. "L'ivoire se dépose par couches concentriques," p. xxvii.; "L'émail se dépose dans un sens contraire à l'ivoire," ib. p. xxviii. And Baron Cuvier again, in the second edition of his "Leçons d'Anatomie Comparée," t. iv. 1836, p. 214: "L'ivoire se dépose par couches, par une sorte de transudation." In the first edition of this classical work, Cuvier had illustrated the peculiarity of the teeth of certain fishes, which are at first detached and afterwards united to the jaw-bone, by comparing their growth to that of the epiphyses of the long bones: "Mais les dents qui ne tiennent qu'à la gencive seulement, comme celle des *Squales*, croissent à la manière des epiphyses des os, c'est-à-dire que toute leur substance osseuse est d'abord tendre et poreuse, et qu'elle se durcit uniformément, et finit par devenir entièrement dure comme de l'ivoire," t. iii. 1805, p. 112. Whether the great anatomist meant to imply that the osseous tissue of the epiphyses of bones was developed differently from osseous tissue in general, *e. g.* by the uniform and simultaneous hardening or calcification, obscurely referred to in the above quotation, may be questioned, for such is not the way in which the teeth of the shark are calcified. But this is certain, that the idea, whatever it might have been, had no influence on the fixed belief of the developement of the dental tissue by transudation expressed in their later and more elaborate works by Baron Cuvier and his accomplished brother; and, in point of fact, the passage which I have quoted is expunged from the second edition of the "Leçons d'Anatomie Comparée," 1835: the successive stages of calcification in the different teeth of the same vertical series in the jaw of the shark, having probably been noticed in the interim by Cuvier.

The author of the article "Sécrétions" in the "Dictionnaire Universel d'Histoire Naturelle," has, however, reproduced Cuvier's obscure comparison of certain fishes' teeth to the epiphyses of bone, as evidence of the needlessness of any ulterior researches for the demonstration of the theory of dental developement by conversion and calcification of the pulp. The passage from the third vol. of the old edition (1800) of the "Leçons d'Anat. Comp.," p. 112, is cited to show that it naturally conducts to the knowledge of such mode of developement of dentine: "En 1840 et 1841 (the 'Comptes Rendus de l'Acad. des Sciences' give the true date) l'étude des dents de Squale par M. R. Owen, lui a démontrée leur accroissement par intussusception, comme elle avait été à G. Cuvier trente-cinq années auparavant." How or why G. Cuvier came to abandon the theory so demonstrated, and how it happened that none of his contemporaries adopted it, M. Duvernoy does not explain. He does give a reason for the omission, in the second edition of the "Leçons d'Anat. Comp." of the passage which he affirms to contain the demonstration: "Malheureusement, le copiste de cet ancien texte pour la 2de édition a omis ce passage, par oubli." It was natural to conclude that its obscurity and seeming contradiction to the theory of dental developement, formally propounded by Cuvier, as well as to the facts shown by nature in the sharks, had been the cause of its omission; but even had the misfortune to which M. Duvernoy now attributes that omission (for in the copious list of addenda and corrigenda to the fifth, 1837, and final, 1846, volumes it is not noticed) not occurred, the coincidence of such passages as the following would still have been inexplicable and irreconcilable with the deductions that M. Dumeril is now enabled to draw from the comparison of the shark's tooth with the epiphyses of long bones. "L'ivoire se dépose par couches, par une sorte de transudation." Leçons d'Anat. Comparée, t. iv., 1836, p. 214. To which proposition Cuvier has himself added a note: "Je me suis assuré récemment, sur des germes de dents d'éléphant, que la substance osseuse de la dent se forme comme

* See the Fasciculus of M. de Blainville's great work, "Ostéographie et Odontographie d'Animaux Vertébrés," which he submitted to the Academy of Sciences of the Institute of France on the same day, December 16th, 1839, on which I communicated, on the occasion of my election as corresponding member of that body, my "Theory of the development of dentine by centripetal calcification and conversion of the cells of the pulp."

les coquilles." And the editor (M. Duvernoy), in order to obviate any possibility of misconception, has himself subjoined a note to that passage, as follows: "L'*ivoire* a été aussi appellé *substance osseuse*, à cause de son analogie de composition chimique et de dureté avec les os. Mais la nature inerte et inorganique de cette substance, mieux appreciée dans ces derniers temps, surtout par les travaux de M. Cuvier, ne permet plus de la désigner, avec justesse, par cette seconde expression. Du moins est-il nécessaire de prémunir le lecteur contre l'ideé fausse qu'il pourrait en tirer, qu'elle serait organisée, qu'elle se développerait à la manière des os."—Tom. cit. p. 201, (1836). In the same spirit in which M. Duvernoy sees (in 1848) that a true idea, instead of a false one, may be drawn from casual expressions and similies loosely applied in the old Leçons of 1800 and 1805; others have sought to depreciate the value of the establishment of the truth by citing the doubts, or tentative approximations made by Purkinje and Schwann to my theory, interpreting such approximations by the light of the established truth. So far from finding such a resting-place for doubt in Cuvier's early simile, cited by M. Duvernoy in 1848, or in the interrogatories of Schwann, nothing short of the investigation of the whole of this vast subject, zootomically, developmentally, and microscopically, as narrated in my "Odontography," sufficed to settle my own doubts; and nothing short of the evidence and illustrations given in that work appeared to me adequate to convert anatomists from the excretion-hypothesis to the intussusception theory.

That the dentine is the ossified pulp is an older notion than that it is an inorganic secretion from such pulp. But an hypothesis, to be of any value in science, must be proved. Almost every true theory has been indicated, with various degrees of approximation, before its final establishment: but he has ever been held, in exact philosophy, to be the author of a theory, by whom it has been first rightly enunciated and satisfactorily established. When time has dissipated the mists of individual or national rivalries and jealousies, the name of the true discoverer is clearly seen by the inextinguishable light of true and impartial history: and to that period I look forward with calm and confident hope.

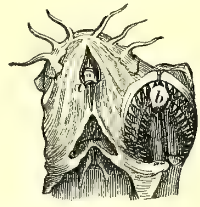
I proceed now to briefly point out the leading characteristics of the teeth in the different classes of the vertebrate animals.

Dental System of Fishes.

The teeth of fishes, whether we study them in regard to their number, form, substance, structure, situation, or mode of attachment, offer a greater and more striking series of varieties than do those of any other class of animals.

As to *number*, they range from zero to countless quantities. The Lancelet, the Ammocete, the Sturgeon, the Paddle-fish, and the whole order of *Lophobranchii*, are edentulous. The Myxinoids have a single pointed tooth on the roof of the mouth (*fig.* 559., *a*), and two serrated dental plates (*b*) on the

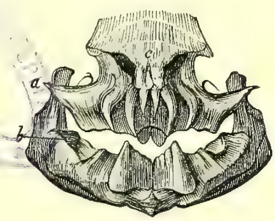
Fig. 559.



Myxine. (*Müller.*)

tongue. The Tench (*fig.* 514. Vol. III. p. 979. art. Pisces)* has a single grinding tooth on the occiput (*c*), opposed to two dentigerous pharyngeal jaws below (*dd*). In the Lepidosiren a single maxillary dental plate (*fig.* 560., *a*) is opposed to a single mandibular

Fig. 560.



Lepidosiren.

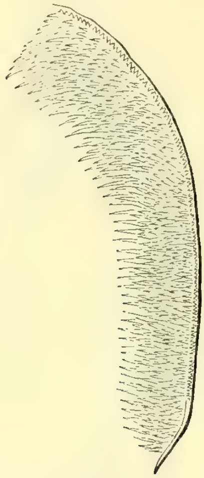
one (*b*), and there are two small denticles on the nasal bone (*c*). In the extinct Sharks with crushing teeth, called *Ceratodus* and *Ctenodus*, the jaws were armed with four teeth, two above and two below.† In the *Chimæræ*, two mandibular teeth are opposed to four maxillary teeth.‡ From this low point the number in different fishes is progressively multiplied until, in the Pike, the Siluroids (*fig.* 561.), and many other fishes, the mouth becomes crowded with countless teeth.

With respect to *form*, I may first observe, that as organised beings withdraw themselves more and more, in their ascent in the scale of life, from the influence of the general polarising forces, so their parts progressively deviate from geometrical figures: it is only, therefore, in the lowest vertebrated class that we find teeth in the form of perfect cubes, and of prisms or plates with three sides (*Myletes*), four sides (*Scarus*), five or six sides, *Myliobates* (*fig.* 562.). The cone is the most common form in fishes: such teeth may be slender, sharp-pointed, and so minute, numerous, and closely aggregated, as to resemble the plush or pile of velvet; these are called "villiform teeth" (*dentes villiformes, dents en velours*§); all the teeth of the Perch are of this kind:

* And Odontography, pl. 57. *fig.* 5.
† See Odontography, pl. 22, *figs.* 2. 6, 7.
‡ Ib., pl. 28, *figs.* 1, 2. 4. 6.
§ The French terms are those used by Cuvier and Valenciennes in their great "Histoire des Poissons," 4to.

when the teeth are equally fine and numerous, but longer, they are called "ciliiform" (*dentes*

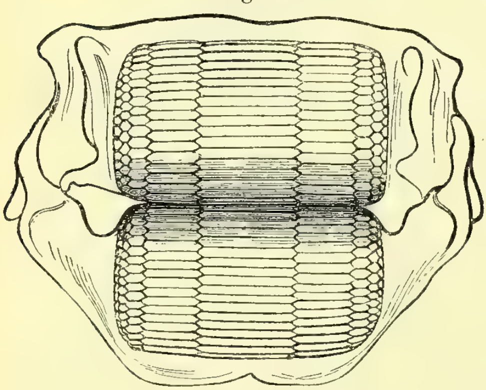
Fig. 561.



Palatine bone and teeth (*Silurus*).

ciliiformes): when the teeth are similar to, but rather stronger than these, they are called

Fig. 562.



Jaws and teeth (*Myliobates*).

"setiform" (*dentes setiformes, dentes en brosse*): conical teeth, as close set and sharp pointed as the villiform teeth, but of larger size, are called "rasp-teeth" (*dentes raduliformes, dents en rape* or *en cardes, fig.* 561.); the Pike presents such teeth on the back part of the vomer: the teeth of the Sheat-fish (*Silurus glanis*) present all the gradations between the villiform and raduliform types. Setiform teeth are common in the fishes thence called Chætodonts*; in the genus *Citharina* they bifurcate at their free extremities; in the genus *Platax* they end there in three diverging points (*fig.* 563.), and the cone here merges into the long and slender cylinder. Sometimes the cone is compressed into a slender trenchant blade: and this may be pointed and

* Χαίτη, bristle; ὀδοὺς, tooth.

recurved, as in the *Muræna;* or barbed, as in *Trichiurus*, and some other Scomberoids; or it may be bent upon itself, like a tenterhook, as in the fishes thence called Goniodonts.* In the Bonito may be perceived a progressive thickening of the base of the conical teeth: and this being combined in other predatory

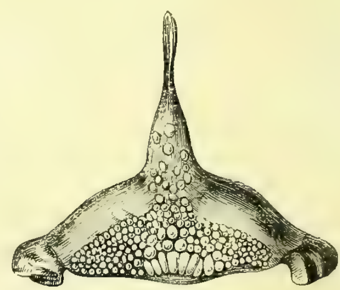
Fig. 563.

Mandibular teeth, magnified (*Platax*).

fishes with increased size and recurved direction, they then resemble the laniary or canine teeth of carnivorous quadrupeds, as we see in the large teeth of the Pike, in the Lophius†, and in certain sharks.‡

The anterior diverging grappling teeth of the wolf-fish form stronger cones; and by progressive blunting, flattening, and expansion of the apex, observable in different fishes, the cone gradually changes to the thick and short cylinder, such as is seen in the back

Fig. 564.



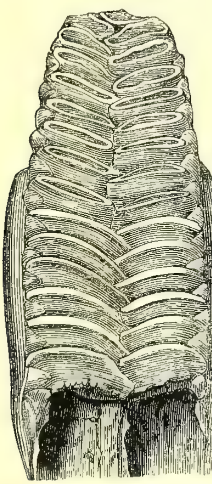
Inferior pharyngeal bone and teeth (*Labrus*).

teeth of the wolf-fish, and in similar grinding and crushing teeth in other genera, whether feeders on sea-weeds, or crustaceous and testaceous animals. The grinding surface of these short cylindrical teeth may be convex, as in the Sheep's-head fish (*Sargus*); or flattened, as in the pharyngeal teeth of the Wrasse (*Labrus*).§ Sometimes the hemispheric teeth are so numerous, and spread over so broad a surface, as to resemble a pavement, as in the pharyngeal bones of the Wrasse or Rock-fish (*Labrus, fig.* 564.); or they may be so small, as well as numerous (*dentes graniformes*), as to give a granulated surface to the part of the mouth to which they are attached (premaxillaries of *Cossyphus*).‖ A progressive increase

* Γωνία, an angle; ὀδοὺς, a tooth.
† Vol. III., *fig.* 512, p. 978. art. Pisces.
‡ Ib. *fig.* 510, p. 976.
§ Ib. *fig.* 513, p. 978.
‖ Odontography, pl. 45, *fig.* 1.

of the transverse over the vertical diameter may be traced in the molar teeth of different fishes, and sometimes in those of the same individual, as in *Labrus* (*fig.* 564.), until the cylindrical form is exchanged for that of the depressed plate. Such dental plates (*dentes lamelliformes*) may be found, not only circular, but elliptical, oval, semilunar, sigmoid, oblong, or even square, hexagonal, pentagonal, or triangular; and the grinding surface may present various and beautiful kinds of sculpturing. The broadest and thinnest lamelliform teeth are those that form the complex grinding tubercle of the Diodon.* The front teeth of the Flounder and Sargus present the form of compressed plates, at least in the crown, and are true *dentes incisivi.* Numerous wedge-shaped dental plates (*dentes cuneati*) are set vertically in the upper pharyngeal bones of the Parrot-fish (*Scarus*, *fig.* 565.). A thin

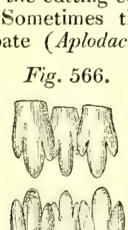
Fig. 565.



Superior pharyngeal bones and teeth (*Scarus*).

lamella, slightly curved like a finger-nail, is the singular form of tooth in an extinct genus of fishes, which I have thence called *Petalodus.* Sometimes the incisive form of tooth is notched in the middle of the cutting edge, as in *Sargus unimaculatus.* Sometimes the edge of the crown is trilobate (*Aplodactylus*, *fig.* 566.).

Fig. 566.



Front teeth of Aplodactylus.

Sometimes it is made quinquelobate by a double notch on each side of the large middle lobe (*Boops*). In the formidable Sea-pike (*Sphyræna Barracuda*) the crown of each tooth, large and small, is produced into a compressed and sharp point, and resembles a lancet. Sometimes the edges of such lancet-shaped teeth are finely serrated, as in *Priodon*, and the great Sharks of the genus *Carcharias*, the fossil teeth of which indicate a species (*Carch. Megalodon*) sixty or seventy feet in length.

The lancetted form is exchanged for the stronger spear-shaped tooth in the Sharks of the genus *Lamna;* and in the allied great extinct *Otodus*, as in the small Porbeagle, similarly shaped, but stronger, piercing and cutting teeth were complicated by one or more accessory compressed cusps on each side their base, like the Malay crease.

With respect to *situation*, the teeth, in Sharks and Rays, are limited to the bones (maxillary and mandibular), which form the anterior aperture of the mouth: in the Carp and other Cyprinoids the teeth are confined to the bones (pharyngeal and basi-occipital) which circumscribe the posterior aperture of the mouth. The Wrasses (*Labrus*) and the Parrot-fishes (*Scarus*) have teeth on the pre-maxillary and pre-mandibular, as well as on the upper and lower pharyngeals; both the anterior and posterior apertures of the mouth being thus provided with instruments for seizing, dividing, or comminuting the food, the grinders being situated at the pharynx. In most fishes teeth are developed also in the intermediate parts of the oral cavity, as on the palatines, the vomer, the hyoid bones, the branchial arches; and, though less commonly, on the pterygoids, the entopterygoids, the sphenoids, and even on the nasal bone (*fig.* 560, *c.*). It is very rare to find teeth developed on the true superior maxillary bones; but the Herring and Salmon tribes, some of the Ganoid Fishes, and the great *Sudis*, are examples of this approach to the higher Vertebrata. Among the anomalous positions of teeth may be cited, besides the occipital alveolus of the Carp*, the marginal alveoli of the prolonged, depressed, well ossified rostrum of the Saw-fish, *Pristis.* In the Lampreys and in *Helostomus* (an osseous fish), most of the teeth are attached to the lips. Lastly, it is peculiar to the class *Pisces*, amongst Vertebrata, to offer examples of teeth developed in the median line of the mouth, as in the palate of the Myxines (*fig.* 559, *a.*); or crossing the symphysis of the jaw, as in *Notidanus*, *Scymnus*, and *Myliobates.*

Nor is the mode less varied than the place of attachment. The teeth of *Lophius*, *Pœcilia*, *Anableps*, are always moveable. In most fishes they are anchylosed to the jaws by continuous ossification from the base of the dental pulp; the histological transition being more or less gradual from the structure of the tooth to that of the bone. Sometimes we find, not the base, but one side of the tooth anchylosed to the alveolar border of the jaw; and the teeth oppose each other by

† Odontography, pl. 38, *fig.* 2; and art. PISCES, Vol. III. p. 980, *fig.* 517.

* Odontography, pl. 8; and art. PISCES, Vol. III., p. 980, *fig.* 518.

their sides instead of their summits (*Scarus**); in *Pimelodus*, however, where the teeth are thus attached, the crown is bent down in the upper teeth, and bent up in the lower ones, at right angles to the fang, so that they oppose each other by the normal surfaces. Certain teeth of recent and fossil cartilaginous fishes have their base divided into processes like fangs, but these serve for the attachment of ligaments, and are not set in bony sockets like the true fangs or roots of the teeth of the Mammalia. Some Sharks have two divaricating fangs; some fossil teeth referred to my genus *Petalodus* by Agassiz, with the specific name "*radicans*," have the base divided into several fangs or processes, indicating a generic distinction. The base of anchylosed teeth is, at first, attached to the jaw-bone by ligament; and in the Cod-fish, Wolf-fish, and some other species, as calcification of the tooth progresses towards its base, the subjacent portion of the jaw-bone receives a stimulus, and developes a process corresponding in size and form with the base of the tooth: for some time a thin layer of ligamentous substance intervenes, but anchylosis usually takes place to a greater or less extent before the tooth is shed. Most of the teeth of the Lophius retain the primitive ligamentous connection; the ligaments † of the large internal or posterior teeth of the upper and lower jaws, radiate on the corresponding sides of the bone, the base of the tooth resting on a conformable alveolar process. The ligaments do not permit the tooth to be bent outwards beyond the vertical position, but yield to pressure in the contrary direction, by which the point of the tooth may be directed towards the back of the mouth; the instant, however, that the pressure is remitted, the tooth returns through the elasticity of the bent ligaments, as by the action of a spring, into its usual erect positions (*fig.* 512, *c. c.* Vol. III. p. 978. art. PISCES); the deglutition of the prey of this voracious fish is thus facilitated, and its escape prevented.‡ The broad and generally bifurcate bony base of the teeth of Sharks is attached by ligament to the semi-ossified crust of the cartilaginous jaws §; but they have no power of erecting or depressing the teeth at will. The small and closely crowded teeth of Rays are also connected by ligaments to the subjacent maxillary and mandibular membranes. The broad tesselated teeth of the *Myliobates* have their attached surface longitudinally grooved to afford them better hold-fast, and the sides of the contiguous teeth are articulated together by serrated or finely undulating sutures, a structure unique in dental organisation.‖ The teeth of the *Sphyræna* are examples of the ordinary implantation in sockets, with the addition of a slight anchylosis of the base of the fully-formed tooth with the alveolar parietes; and the compressed rostral teeth of the Saw-fish are deeply implanted in sockets. In the latter the hind margin of their base is grooved, and a corresponding ridge from the back part of the socket fits into the groove, and gives additional fixation to the tooth. Some implanted teeth in the present class have their hollow base further supported, like the claws of the feline tribe, upon a bony process arising from the base of the socket; the incisors of the Balistes, *e.g.*, afford an example of this double or reciprocal gomphosis. In fact, the whole of this part of the organisation of fishes is replete with beautiful instances of design, and instructive illustrations of animal mechanics. The vertical section of a pharyngeal jaw and teeth of the Wrasse (*Labrus* *) would afford the architect a model of a dome of unusual strength, and so supported as to relieve from pressure the floor of a vaulted chamber beneath. The base of the dome-shaped tooth is slightly contracted, and is implanted in a shallow circular cavity; the rounded margin of which is adapted to a circular groove in the contracted part of the base; the margin of the tooth which immediately transmits the pressure of the bone, is strengthened by an inwardly projecting convex ridge. The masonry of this inner buttress, and of the dome itself, is composed of hollow columns, every one of which is placed so as best to resist or transmit in the due direction the external pressure. The floor of the alveolus is thus relieved from the office of sustaining the tooth: it forms, in fact, the roof of a lower vault, in which the germ of a successional tooth is in course of development; had the crushing tooth in use, rested, as in the Wolf-fish, by the whole of its base upon the alveolus, the supporting plate, gradually undermined by the growth of the new tooth, must have given way, and been forced upon the subjacent delicate and highly vascular and sensitive matrix of the half-formed tooth. But the superincumbent pressure is exclusively sustained by the border of the alveolus, whence it is transferred to the walls dividing the vaulted cavities containing the germs of the new teeth; the roofs of these cavities yield to the absorbent process consequent on the growth of the new teeth without materially weakening the attachment of the old teeth, and without the new teeth being subjected to any pressure until their growth is sufficiently advanced to enable them to bear it with safety; by this time the sustaining borders of the old alveolus are undermined, and the old worn-down tooth is shed.

The singular and powerfully developed dental system of the Wolf-fish (*Anarrhichas Lupus*) has been a subject of interest to many anatomists. The general character and physiological relations of the teeth in this species had not escaped the attention of Hunter. In his paper on the Gillaroo trout, read before the Royal Society in 1774, he observes that "the teeth of fishes which subsist

* Odontography, pl. 49; and art. PISCES, Vol. III. *fig.* 516, p. 979.

† See art. PISCES, Vol. III., *fig.* 512 *d*, p. 978.

‡ Odontography, p. 154.

§ Art. PISCES, Vol. III., *fig.* 510, p. 976.

‖ Odontography, p. 46. pl. 27 *c*.

* *Fig.* 544; and art. PISCES, Vol. III., *fig.* 513, p. 978.

chiefly on animal matter must vary according as their food may be common salt fish, or shell-fish." "Such fish as live on the first kind have, like the carnivorous quadrupeds and birds, no apparatus for mastication, their teeth being intended merely for catching the food and fitting it to be swallowed. But the shells of the second kind of food render some degree of masticatory power necessary to fit it for its passage either into the stomach or through the intestines: and accordingly we find in certain fish a structure suited to the purpose. Thus the mouth of the Wolf-fish is almost paved with teeth, by means of which it can break shells to pieces, and fit them for the œsophagus of the fish, and so effectually disengage the food from them, that though it lives upon such hard food, the stomach does not differ from that of other fish."

But in order to secure the capture of the shell-fish, the teeth of the Wolf-fish are not all crushers; some present the laniary type, with the apices more or less recurved and blunted by use, and consist of strong cones spread abroad, like grappling hooks, at the anterior part of the mouth.*

The premaxillary teeth are all conical, and arranged in two rows; there are two, three, or four in the exterior row, at the mesial half of the bone, which are the largest; and from six to eight smaller teeth are irregularly arranged behind. There are three large, strong, diverging laniaries at the anterior end of each premandibular bone, and immediately behind these an irregular number of shorter and smaller conical teeth, which gradually exchange this form for that of large obtuse tubercles; these extend backwards, in a double alternate series, along a great part of the alveolar border of the bone, and are terminated by two or three smaller teeth in a single row, the last of which again presents the conical form. Each palatine bone supports a double row of teeth, the outer ones being conical and straight, and from four to six in number; the inner ones two, three, or four in number, and tuberculate. I have seen a specimen where the inner row was wanting on one side. The lower surface of the vomer is covered by a double irregularly alternate series of the same kind of large tuberculate crushing teeth as those at the middle of the premandibular. All the teeth are anchylosed to more or less developed alveolar eminences, like the anterior teeth of the *Lophius*. The periphery of the expanded circular base of the large anterior grappling teeth is divided into processes indicative of the original ligamentous fasciculi at the base of the pulp by the ossification of which their anchylosis is effected.

When such anchylosed teeth and the supporting bone are divided by a vertical section, as in *fig.* 2, pl. 66, of my "Odontography," there may be generally discerned a faint transverse line indicating the original separation between the tooth and the bone, and more clearly defining the dental from the osseous structure, than in the anchylosed teeth of other fishes. From the enormous development of the muscles of the jaws, and the strength of the shells of the whelks and other testacea which are cracked and crushed by the teeth, their fracture and displacement must obviously be no unfrequent occurrence; and most specimens of the jaws of the Wolf-fish exhibit some of the teeth either separated at this line of imperfect anchylosis, or, more rarely, broken off above the base, or, still more rarely, detached by fracture of the supporting osseous alveolar process.

With regard to the *substance* of the teeth of fishes, the modifications of dentine, called vaso-dentine and osteo-dentine *, predominate much more than in the higher Vertebrata; and they thus more closely resemble the bones which support them. There is, however, great diversity in respect of substance. The teeth of most of the Chætodonts are flexible, elastic, and composed of a yellowish subtransparent albuminous tissue; such, likewise, are the labial teeth of the Helostome, the premaxillary and mandibular teeth of the Goniodonts, and of that percoid genus thence called *Trichodon*. In the Cyclostomes the teeth consist of a denser albuminous substance. The upper pharyngeal molar of the Carp consists of a peculiar brown and semitransparent tissue, hardened by salts of lime and magnesia. The teeth of the Flying-fish (*Exocœtus*), and Sucking-fish (*Remora*), consist of osteo-dentine. In many fishes, *e.g.* the *Acanthurus*, *Sphyræna*, and certain Sharks (*Lamna*, *fig.* 545.), a base, or body of osteo-dentine is coated by a layer of true dentine, but of unusual hardness, like enamel: in *Prionodon* this hard tissue predominates. In the *Labrus* the pharyngeal crushing teeth consist wholly of hard or unvascular dentine (*fig.* 544.). In most Pycnodonts and Cestracionts, and many other fishes, the body of the tooth consists of ordinary unvascular dentine, covered by a modification of that tissue which I have called "vitro-dentine" from its clear, polished, enamel-like character: but this is not enamel, nor the product of a distinct organ from the dentinal pulp: it differs from ordinary dentine in the greater proportion of the mineral particles, their more minute diffusion through the gelatinous basis, in the straighter course and more minute size of the calcigerous tribes; it results from the calcification of the external layer of the dentinal pulp, and is the first part of the tooth which is formed. In *Sargus* and *Balistes* the body of the tooth consists of true dentine, and the crown is covered by a thick layer of a denser tissue, developed by a distinct organ, and differing from the "enamel" of higher animals only in the more complicated and organised mode of deposition of the earthy salts. The ossification of the capsule of the complex matrix of these teeth covers the enamel with a thin coating of "cement." In the pharyngeal

* Odontography, pl. 60, 61.

* Odontography, Introduction, p. lxxii.

teeth of the *Scarus* a fourth substance is added by the ossification of the base of the pulp after its summit and periphery have been converted into hard dentine; and the teeth (*fig.* 558.), thus composed of cement (*c*), enamel (*e*), dentine (*d*), and osteo-dentine, are the most complex in regard to their substance that have yet been discovered in the animal kingdom.

The tubes which convey the capillary vessels through the substance of the osteo- and vaso-dentine of the teeth of fishes* were early recognised, on account of their comparatively large size; as by André, *e.g.* in the teeth of *Acanthurus*, and by Cuvier and Von Born in the teeth of the Wolf-fish and other species. Leeuwenhoek had also detected the much finer tubes of the peripheral dentine of the teeth of the Haddock. These "dentinal tubuli" are given off from the parietes of the vascular canals, and bend, divide, and subdivide rapidly in the hard basis-tissue of the interspaces of those canals in osteo-dentine; the dentinal tubuli alone are found in true dentine, and they have a straighter and more parallel course, usually at right angles to the outer surface of the dentine. Those conical teeth which, when fully formed, consist wholly or in great part of osteo-dentine or vaso-dentine, always first appear with an apex of hard or true dentine. In some fishes the simple central basal pulp-cavity of such teeth, instead of breaking up into irregular or parallel canals, sends out a series of vertical plates from its periphery, which, when calcified, give a fluted character to the base of the tooth, *e.g.* in *Lepidosteus oxyurus.*† Sometimes such radiating vertical basal plates of dentine are wavy in their course, and send off narrow processes from their sides; and, as a thin layer of the outer capsule interdigitates with the outstanding plates of the dentinal pulp, and becomes co-calcified with them, a transverse section of such a tooth presents a series of interblended wavy or labyrinthic tracts of thick dentine radiating from the centre, and of thin cement converging towards the centre of the tooth.‡ An analogous but more complicated structure obtains when the radiating, wavy, vertical plates of dentine dichotomise, and give off from their sides, throughout their course, numerous branch plates and processes, which are traversed by medullary sinuses and canals with their peripheral terminations dilated, and becoming the centres of lobes or columns of hard dentine. The transverse section of such teeth gives the appearance of branches of a tree, with leaf-stalks and leaves, radiating from the central pulp-cavity to the circumference of the tooth; and I have called the fossil fish in which this structure was first detected, *Dendrodus*.

Thus, with reference to the main and fundamental tissue of tooth, we find not fewer than six leading modifications in fishes;—hard or true dentine (*Sparoids, Labroids, Lophius, Balistes, Pycnodonts, Prionodon, Sphyræna, Megalichthys, Rhizodus, Diodon, Scarus*); osteo-dentine (*Cestracion, Acrodus, Lepidosiren, Ctenodus, Hybodus, Percoids, Sciænoids, Cottoids, Gobioids,* and many others); vaso-dentine (*Psammodus, Chimæroids, Pristis, Myliobates*); plici-dentine (*Lophius, Holoptychius, Lepidosteus oxyurus,* at the base of the teeth); labyrintho-dentine (*Lepidosteus platyrhinus, Bothriolepis*); and dendro-dentine (*Dendrodus*); besides the compound teeth of the *Scarus* and *Diodon*.

One structural modification may prevail in some teeth, another in other teeth of the same fish; and two or more modifications may be present in the same tooth, arising from changes in the process of calcification and a persistency of portions or processes of the primitive vascular pulp or matrix of the dentine.

The dense covering of the beak-like jaws of the Parrot-fishes (*Scari*), consists of a stratum of prismatic denticles, standing almost vertically to the external surface of the jaw-bone. An account of the structure and development of this peculiar armature of the jaws is abridged from my "Odontography" (pp. 112—116.), in the article PISCES (Vol. III. p. 979.). It is peculiarly adapted to the habits and exigencies of a tribe of fishes which browse upon the lithophytes that clothe, as with a richly tinted carpet, the bottom of the sea, just as the Ruminant quadrupeds crop the herbage of the dry land.

The irritable bodies of the gelatinous polypes which constitute the food of these fishes retract, when touched, into their star-shaped stony shells, and the Scari consequently require a dental apparatus strong enough to break off or scoop out these calcareous recesses. The jaws are, therefore, prominent, short, and stout, as shown in *fig.* 515. p. 979. Vol. III.; and the exposed portions of the premaxilliaries and premandibulars are encased by the complicated dental covering represented in *figs.* 515 and 516. Vol. III.

The polypes and their cells are reduced to a pulp by the action of the pharyngeal jaws

* The vaso-dentine of *Pristis* and *Myliobates* is like that of the teeth of the Cape Anteater (*Orycteropus*): the vaso-dentine of the Psammodonts resembles that which forms the base of the tooth of the Sloth and Megatherium: the vaso-dentine of Mammals differs from the osteo-dentine in the absence of the radiated "Purkinjian," cells.

† Wyman, American Journal of Natural Sciences, Oct. 1843. Cuvier has given an accurate view of the plaited structure of the base of the Wolf-fish's teeth in pl. 32, *fig.* 7. of his Leçons d'Anatomie Comparée, 1805; where it is described at the base of the osseous tubercle, which supports the true tooth.

‡ This remarkable structure attains its highest complication and forms the largest proportion of the tooth in the gigantic extinct labyrinthodont Batrachia, and from which, therefore, I have taken the illustrations of that complex modification of dental structure (*fig.* 552.). I had discovered in 1841 the more simple modification of this structure "at the base of the tooth in a few fishes" (Geol. Trans., 2d series, vol. vi., p. 507), but had not then seen so complex an example in that class as Dr. Wyman and M. Agassiz (Recherches sur les Poissons Fossiles, "Sauroides," 1843) subsequently described and figured, in teeth of the genus *Lepidosteus*.

and teeth, that close the posterior aperture of the mouth.

The superior dentigerous pharyngeals (*figs.* 558. and 565.) present the form of an elongated, vertical, inequilateral, triangular plate; the upper and posterior margin is sharp and concave; the upper and anterior margin forms a thickened articular surface, convex from side to side, and playing in a corresponding groove or concavity upon the base of the skull; the inferior boundary of the triangle is the longest, and also the broadest; it is convex in the antero-posterior direction, and flat from side to side. It is on this surface that the teeth are implanted, and in most species they form two rows; the outer one consisting of very small, the inner one of large dental plates, which are set nearly transversely across the lower surface of the pharyngeal bone, and are in close apposition, one behind the other: their internal angles are produced beyond the margin of the bone, and interlock with those of the adjoining bone when the pharyngeals are in their natural position; the smaller denticles of the outer row are set in the external interspaces of those of the inner row.

The single inferior pharyngeal bone consists principally of an oblong dentigerous plate, of the form represented in *fig.* 3, pl. 51, of my "Odontography;" its breadth somewhat exceeds that of the conjoined dentigerous surface of the pharyngeals above, and it is excavated to correspond with their convexity. This dentigerous plate is principally supported by a strong, slightly curved, transverse, osseous bar, the extremities of which expand into thick obtuse processes for the implantation of the triturating muscles. A longitudinal crest is continued downwards and forwards from the middle line of the inferior pharyngeal plate, anterior to the transverse bar, to which the protractor muscles are attached.

A longitudinal row of small oval teeth alternating with the large lamelliform teeth, like those of the superior pharyngeals, bounds the dentigerous plate on each side; the intermediate space is occupied exclusively by the larger lamelliform or wedge-shaped teeth, set vertically in the bone, and arranged transversely in alternate and pretty close set series.

The dental plates are developed in wide and deep cavities in the substance of the posterior part of the lower, and of the anterior part of the upper pharyngeal bones. Each denticle is developed in its proper capsule, which contains an enamel-forming pulp and a dentinal pulp, in close cohesion with each other and with the thin external capsule. The teeth exhibit progressive stages of formation as they approach the posterior part of the upper and the anterior part of the lower pharyngeal bones: as their formation advances to completion they become soldered together by ossification of their respective capsules into one compound tooth, which soon becomes anchylosed by ossification of the dentinal pulp to the pharyngeal bone itself.

The dentine of the pharyngeal teeth of the Scarus consists of calcigerous tubes and a clear intermediate substance. The calcigerous tubes average a diameter of $\frac{1}{20,000}$ of an inch, and are separated by interspaces equal to twice their own diameter. The course of these tubes is shown in *fig.* 558, *d.*, in which they are exposed by a vertical section through the middle of two of the superior denticles. They all, on leaving the pulp-cavity, form a curve with the convexity turned towards the base of the tooth, and then bend slightly in the opposite direction; the sigmoid curve being most marked in the calcigerous tubes at the base of the denticles, whilst those towards the apex become longer and straighter. Besides the primary curvatures exemplified in the figure, each calcigerous tube is minutely undulated; it dichotomises three or four times near its termination, sends off many fine lateral branches into the clear uniting substance, and finally terminates in a series of minute cells and inosculating loops at the line of junction with the enamel.

This substance (*fig.* 558, *e.*) is as thick as the dentine, and consists of a similar combination of minute tubes and a clear connecting substance. The tubes may be described as commencing from the pheripheral surface of the tooth to which they stand at right angles, and, having proceeded parallel to each other halfway towards the dentine, they then begin to divide and subdivide, the branches crossing each other obliquely, and finally terminating in the cellular boundary between the enamel and dentine.

The teeth which present this complex structure are successively developed at one extremity of the bone, in proportion as they are worn away at the other; not, however, as Cuvier describes, from behind forwards, in both upper and lower pharyngeal bones, but in opposite directions in the opposite bones, the course of succession being from before backwards in the upper, and from behind forwards in the lower pharyngeal bones. In the progress of the attrition to which they are subjected, the thin coat of cement resulting from the ossification of the capsule is first removed from the apex of the tooth, then the enamel constituting that apex, next the dentine, and, finally, the coarse central cellular bone, supporting the hollow wedge-shaped tooth; and thus is produced a triturating surface of four different substances of different degrees of density. The enamel, being the densest element, appears in the form of elliptical transverse ridges, inclosing the dentine and central bone; and external to the enamel is the cement which binds together the different denticles.

There is a close analogy between the dental mass of the Scarus and the complicated grinders of the elephant, both in form, structure, and in the reproduction of the component denticles in horizontal succession. But in the fish, the complexity of the triturating surface is greater than in the Mammal, since, from the mode in which the wedge-shaped denticles of the Scarus are implanted upon, and anchylosed to, the processes of the supporting bone, this likewise enters into the formation of the masticatory surface when the tooth is worn down to a certain point.

The proof of the efficacy of the complex masticatory apparatus above described is afforded by the contents of the alimentary canal of the Scari. Mr. Charles Darwin, the accomplished naturalist and geologist, who accompanied Captain Fitzroy, R. N., in the circumnavigatory voyage of the "Beagle," dissected several Parrot-fishes soon after they were caught, and found the intestines laden with nearly pure chalk, such being the nature of their excrements; whence he ranks these fishes among the geological agents to which is assigned the office of converting the skeletons of the Lithophytes into chalk.

Development.—As might have been anticipated from the discovery of the varied and predominating vascular organisation in the teeth of fishes, and the passage from non-vascular dentine to vascular dentine in the same tooth, the true law of the development of dentine "by centripetal metamorphosis and calcification of the cells of the pulp," was first definitely enunciated and illustrated from observations made on the development of the teeth of fishes.*

It is interesting to observe in this class the process arrested at each of the well-marked stages through which the development of a mammalian tooth passes. In all fishes the first step is the simple production of a soft vascular papilla from the free surface of the buccal membrane: in Sharks and Rays these papillæ do not proceed to sink into the substance of the gum, but are covered by caps of an opposite free fold of the buccal membrane; these caps do not contract any organic connection with the papilliform matrix, but, as this is converted into dental tissue, the tooth is gradually withdrawn from the extraneous protecting cap, to take its place and assume the erect position on the margin of the jaw (*fig.* 510, *b*, *a*, art. PISCES, Vol. III. p. 976.). Here, therefore, is represented the first and transitory "papillary" stage of dental development in Mammals; and the simple crescentic cartilaginous maxillary plate, with the open groove behind containing the germinal papillæ of the teeth, offers in the Shark a magnified representation of the earliest condition of the jaws and teeth in the human embryo.

In many fishes, e. g. *Lophius*, *Esox*, the dental papillæ become buried in the membrane from which they rise, and the surface to which their basis is attached becomes the bottom of a closed sac: but this sac does not become inclosed in the substance of the jaw; so that teeth at different stages of growth are brought away with the thick and soft gum, when it is stripped from the jaw-bone. The final fixation of teeth, so formed, is effected by the development of ligamentous fibres in the submucous tissue between the jaw and the base of the tooth, which fibres become the medium of connection between those parts, either as elastic ligaments, or by continuous ossification. Here, therefore, is represented the "follicular" stage of the development of a mammalian tooth; but the "eruptive" stage takes place without previous inclosure of the follicle and matrix in the substance of the jaw-bone.

In *Balistes*, *Scarus*, *Sphyræna*, the Sparoids, and many other fishes, the formation of the teeth presents all the usual stages which have been observed to succeed each other in the dentition of the higher *Vertebrata:* the papilla sinks into a follicle, becomes surrounded by a capsule, and is then included within a closed alveolus of the growing jaw (*fig.* 516. *c*, Vol. III. p. 979. art. PISCES), where the developement of the tooth takes place and is followed by the usual eruptive stages. A distinct enamel-pulp is developed from the inner surface of the capsule in *Balistes*, *Scarus*, *Sargus*, and *Chrysophrys*.

The most formidable dentition exhibited in the order of osseous fishes, is that which characterises the *Sphyræna*, and some extinct fishes allied to this predatory genus. In the great Barracuda of the southern shores of the United States (*Sphyræna Barracuda*, Cuv.), the lower jaw contains a single row of large, compressed, conical, sharp-pointed, and sharp-edged teeth, resembling the blades of lancets, but stronger at the base. The two anterior of these teeth are twice as long as the rest, but the posterior and serial teeth gradually increase in size towards the back part of the jaw; there are about twenty-four of these piercing and cutting teeth in each premandibular bone. They are opposed to a double row of similar teeth in the upper jaw, and fit into the interspace of these two rows when the mouth is closed. The outermost row is situated on the intermaxillary, the innermost on the palatine bones; there are no teeth on the vomer or superior maxillary bones. The two anterior teeth in each premaxillary bone equal the opposite pair in the lower jaw in size: the posterior teeth are serial, numerous, and of small size; the second of the two anterior large premaxillary teeth is placed on the inner side of the commencement of the row of small teeth, and is a little inclined backwards. The retaining power of all the large anterior teeth is increased by a slight posterior projection, similar to the barb of a fish-hook, but smaller. The palatine bones contain each nine or ten lancet-shaped teeth, somewhat larger than the posterior ones of the lower jaw. All these teeth afford good examples of the mode of attachment by implantation in sockets, which has been denied to exist in fishes.*

The loss or injury to which these destructive weapons are liable in the conflict which the *Sphyræna* wages with its living and

* In my Hunterian Lectures, delivered at the Royal College of Surgeons, May, 1839. See also, Compte Rendu de l'Académie des Sciences, Dec. 1839, p. 784.; and Odontography, Introduction, and part i. *passim.*

* Cuvier, Histoire Naturelle des Poissons, tom. i. p 492.

struggling prey, is repaired by an uninterrupted succession of new pulps and teeth. The existence of these is indicated by the foramina, which are situated immediately posterior to, or on the inner margin of, the sockets of the teeth in place; these foramina lead to alveoli of reserve, in which the crowns of the new teeth in different stages of development are loosely embedded. It is in this position of the germs of the teeth that the Sphyrænoid fishes, both recent and fossil, mainly differ, as to their dental characters, from the rest of the Scomberoid family, and proportionally approach the Sauroid type. The base or fang of the fully-developed tooth of the *Sphyræna* is anchylosed to the parietes of the socket in which it is inserted. The pressure of the crown of the new tooth excites absorption of the inner side of the base of the old, which thus finally loses the requisite strength of attachment; and its loss is followed by the absorption of the old socket, as in the higher animals.

It is interesting to observe that the alternate teeth are, in general, contemporaneously shed; so that the maxillary armour is always preserved in an effective state. The relative position of the new teeth to their predecessors, and their influence upon them, resembles, in the *Sphyræna,* some of the phenomena which will be described in the dentition of the crocodilian reptiles. To the crocodiles the present voracious fish also approximates in the alveolar lodgment of the teeth; but it manifests its ichthyic character in the anchylosis of the fully-developed teeth to their sockets, and still more strikingly in the intimate structure of the teeth.

In all fishes the teeth are shed and renewed, not once only, as in Mammals, but frequently, during the whole course of their lives. The maxillary dental plates of *Lepidosiren,* the cylindrical dental masses of the Chimæroid and Edaphodont fishes, and the rostral teeth of *Pristis* (if these modified dermal spines may be so called) are, perhaps, the sole examples of "permanent teeth" to be met with in the whole class.

When the teeth are developed in alveolar cavities, they are usually succeeded by others in the vertical direction, as in the pharyngeal bones of the Labroids (*fig.* 513., art. PISCES, Vol. III. p. 978.); but sometimes they follow one after the other, side by side, as in the Scaroids (PISCES, *fig.* 516. *c,* p. 979.). The successional teeth owe the origin of their matrix to the budding out from the capsule of their predecessors of a cæcal process, in which the papillary rudiment of the dentinal pulp is developed according to the laws explained in the Introduction to my "Odontography," and the article TOOTH. But, in the great majority of fishes, the germs of the new teeth are developed, like those of the old, from the free surface of the buccal membrane throughout the entire period of succession; a circumstance peculiar to the present class. The Angler, the Pike, and most of our common fishes, illustrate this mode of dental reproduction; it is very conspicuous in the cartilaginous fishes, in which the whole phalanx of their numerous teeth is ever marching slowly forwards in rotatory progress over the alveolar border of the jaw, the teeth being successively cast off as they reach the outer margin, and new teeth rising from the mucous membrane behind the rear rank of the phalanx.

This endless succession and decadence of the teeth, together with the vast numbers in which they often coexist in the same fish, illustrate the law of Vegetative or Irrelative Repetition, as it manifests itself on the first introduction of new organs in the animal kingdom, under which light we must view the above-described organised and calcified preparatory instruments of digestion in the lowest class of the vertebrate series.

At the extreme limit of the class of fishes, and connecting that class with the reptiles, stands the very remarkable genus, the dental system of which is figured in cut 560. This consists of two small, slender, conical, sharp-pointed, and slightly recurved teeth, which project downwards from the nasal bone (*c*), and of strong trenchant dental plates anchylosed with the alveolar border of the upper (*a*) and lower (*b*) jaws, in each of which the plate is divided at the middle, or symphysial line, so as to form two distinct lateral teeth.

The office of the two laniariform teeth is to pierce and retain the nutritive substance or prey which is afterwards divided and comminuted by the strong maxillary dental plates.

The upper pair of these plates is supported by the anterior part of a strong arch of bone, which combines the characters of the superior maxillary, palatine, and pterygoid bones; the superior maxillary is represented by the median and anterior bar, passing in front of the dental plate of the lower jaw when the mouth is shut, terminating on each side in a process which projects outwards and backwards, as in *fig.* 560., *a.*, on each side of the anterior part of the arch; the palatine portion constitutes the median part of the roof of the mouth behind the foregoing; the pterygoid portion is indicated by its fulfilling the usual function of an abutment extended between the palatine portion of the upper jaw and the articular pedicle of the lower jaw; the upper dental plates are confined to the first two parts of the arch (maxillary and palatine), and do not extend upon the pterygoid portion; the lower dental plates (*b*) are anchylosed to the premandibular bone. Viewing the upper pair of plates as a single tooth, it may be described as indented at its outer surface by five vertical angular notches, penetrating inwards through half the breadth of the supporting bone, and dividing the plate into six angular processes, which, from the direction and varying form and breadth of the entering notches, radiate from the posterior part of the median line or division of the tooth. The inferior dental plate is similarly notched on its outer side, but the proportions of the angular indentations are such, that they receive all the processes of the upper dental plate when the mouth is shut, whilst only the four anterior processes are reciprocally received into the notches of the upper dental plate, this, with the supporting arch, being anterior to the lower plate,—a position which is decisive in favour of its maxillary character, and against its homology with the vomer.

The dental plate consists, as in the Cod and *Sphyræna*, of a central mass of coarse osseous substance, traversed by large and nearly parallel medullary canals, and an external sheath of very hard "vitro-dentine." The medullary canals are continued from a coarse reticulation of similar but wider canals in the substance of the supporting bone, and advance forwards, nearly parallel with each other and with the plane of the upper surface of the tooth; they anastomose together by short, curved, transverse canals, which intercept spaces increasing in length as the canals recede from the osseous basis. The canals themselves diminish in size in the same ratio; and when they have arrived near the dense outer layer, their divisions and inosculations become again more frequent, the peripheral loops forming a well-marked line of demarcation between the coarse-tubed and the fine-tubed dentine. The interspaces of the medullary canals are occupied by a clear substance, and by moss-like reticulations of fine dentinal tubes, which appear to be more sparing in number than in the teeth of the *Sphyræna* or Shark. The dentinal tubes of the vitro-dentine run nearly parallel to each other, and vertically to the external surface of the dental plate through about two-thirds of the thickness of that tissue; they then bend and cross each other in a manner very similar to those of the vitro-dentine in the teeth of the *Lepidotus*, *Phyllodus*, &c.*

In the process of attrition this external dense substance is worn away from the upper surface of the dental processes in the lower jaw, exposing the softer vaso-dentinal substance of the tooth; in this state the dental plate offers an analogy to the incisors of the Rodents, a posterior softer substance being sheathed by an anterior denser layer; and an external sharp edge is similarly kept up by the unequal wearing away of the two substances. The progressive waste at the upper surface of the dental plate would appear to be met by a corresponding additon of new material to its lower part.

In the structure here presented we have a condition of the dentine which has hitherto been met with only in the class of fishes.

The test of the affinities of the present paradoxical genus, afforded by the microscopic examination of the teeth, gives additional confirmation to the view to which I have been led, from arguments drawn from the rest of its organisation, that the *Lepidosiren* is in every essential point a member of the class of fishes.†

* See Odontography, pp. 70. 166, pl. 59, *fig.* 4.

† Linnean Transactions, vol. xviii. 1839. p. 350. That the large size, or elliptical form of its blood-discs should outweigh the cumulative evidence establishing the piscine nature of the *Lepidosiren* could only be surmised by those who are ignorant of the variation in size and shape which the blood-discs present in the class of fishes, and the consequent unimportance of those particles as a character of the class. As well might the *Petromyzon* be deemed a mammal because its blood-discs are circular and comparatively small, as the *Lepidosiren* be held to be a Batrachian because its blood-discs are elliptical and comparatively large.

Dental System of Reptiles.

If we compare the dental system of the foregoing Batrachoid fish with that in the true *Batrachia*, it is only to the larval state of the Anourans that an analogy can be found; the tadpole of the frog having its maxilla and mandibula each sheathed with a single and continuous horny dental trenchant covering. Were this sheath actually dentinal in tissue and united to the jaw-bone, the resemblance to the *Lepidosiren* would be closer; but in point of fact the analogy is very remote; the horny beak of the tadpole is never calcified or anchylosed, but is shed during the progress of the metamorphosis.* The Siren alone, among the larval-like perennibranchiate reptiles, retains the sheath upon the extremity of the upper and lower jaws; it consists of a firm albuminous tissue, and becomes harder than horn. But these trenchant mandibles, which play upon one another like the blades of a pair of curved scissors, are associated with numerous small but distinct true teeth, which are grouped together to form a rasp-like surface on each half of the divided vomer, and which beset the alveolar border of the splenial element of the mandible below.

In the class *Reptilia*, the whole order of *Chelonia* is edentulous, as well as the whole family of Toads (*Bufonidæ*) in the order *Batrachia;* certain extinct genera of Saurians were likewise edentulous, *e.g.* the remarkable "*Rhynchosaurus*" of the new red sandstone of Shropshire, and some of the extinct Saurians of South Africa.

In the tortoises and turtles the jaws are covered by a sheath of horn, which in some species is of considerable thickness and very dense; its working surface is trenchant in the carnivorous species, but variously sculptured, and adapted for both cutting and bruising in the vegetable feeders; it may be said that the transitory condition of the mandibles of the Batrachian larvæ is here persistent.

The development of the continuous horny maxillary sheath commences, as in the parrot tribe, from a series of distinct papillæ, which sink into alveolar cavities, regularly arranged (in *Trionyx*) along the margins of the upper and lower jaw-bones: these alveoli are indicated by the persistence of vascular canals long after the originally separate tooth-like cones have become confluent, and the horny sheath completed.

The teeth of the dentigerous Saurian,

* The large dental plates of *Lepidosiren* have their nearest homologues in those of the extinct fish called *Ceratodus* (Odontography, pl. 22, *fig.* 2.).

Ophidian, and Batrachian reptiles, are, for the most part, simple and adapted for seizing and holding, but not for dividing or masticating their food. The Siren alone combines true teeth with a horny maxillary trenchant sheath, like that of the Chelonian reptiles.

With respect to *number*, in no existing reptile are the teeth reduced so low as in certain mammals and fishes; nor, on the other hand, are they ever so multiplied as in many of the latter class. The extinct Dicynodont reptiles of South Africa had but two teeth, which were long tusks implanted in the upper jaw.* Some species of *Amphisbœna* (*A. alba*), with fifteen teeth in the upper jaw and fourteen in the lower jaw, and certain Monitors (*Varanus*), with sixteen teeth in the upper and fourteen in the lower jaw, afford examples of the smallest number of teeth amongst existing reptiles; and certain Batrachians, with teeth "en cardes" at the roof of the mouth, or which have upwards of eighty teeth in each lateral maxillary series, present the largest number. It is rarely that the number of the teeth is fixed and determinate in any reptile so as to be characteristic of the species, and still more rarely have the individual teeth such characters as to be determined homologically from one species to another.

With respect to *situation*, the teeth may be present on the jaws only, *i.e.* the maxillary, premaxillary, and mandibular bones, as in the crocodiles and many lizards: or upon the jaws and roof of the mouth; and here either upon the pterygoid bones, as in the Iguana and Mosasaur, or upon both palatine and pterygoid bones, as in most serpents, or upon the vomer, as in most Batrachians, or upon both vomerine and pterygoid bones, as in the Axolote; or upon the vomerine and sphenoid bones, as in the *Salamandra glutinosa*, Maclure. With respect to the marginal or jaw teeth, these may be absent in the intermaxillary bones, as in many serpents; or they may be present in the upper and not in the lower jaw, as in most frogs; or in both upper and lower jaws, as in the tailed Batrachians; and among these they may be supported, upon the lower jaw, by the premandibular or dentary piece, as in the Salamanders, Menopome, Amphiume, Proteus; or upon the splenial piece, as in the Siren; or upon both splenial and premandibular bones, as in the Axolotl. The palatine and pterygoid teeth may, in the Batrachians, be arranged in several rows, like the "dents en cardes" of fishes. The sphenoid and splenial teeth are always so arranged in the few species that possess them. The intermaxillary, maxillary, and premandibular teeth are uniserial, or in one row, with the exception of the Cæcilia and the extinct Labyrinthodonts, which have a double row of teeth at the anterior part of the lower jaw.

The teeth of reptiles, with few exceptions, present a simple conical *form*, with the crown more or less curved, and the apex more or less acute. The cone varies in length and thickness; its transverse section is sometimes circular, but more commonly elliptical or oval, and this modification of the cone may be traced through every gradation, from the thick, round, canine-like tooth of the crocodile, to the sabre-shaped fang of the Varanus, the Megalosaur, and the Cladeiodon.* Sometimes, as in the fully formed teeth of the Megalosaur, one of the margins of the compressed crown of the tooth is trenchant, sometimes both are so; and these may be simply sharp-edged, as in the Varanus of Timor, or finely serrated, as in the great Varanus, the Cladeiodon, and the Megalosaur.†

The outer surface of the crown of the tooth is usually smooth; it may be polished, as in the Leiodon, or impressed with fine lines, as in the Labyrinthodon (*fig.* 551.), or raised into many narrow ridges, as in the Pleiosaur and Polyptychodon, or broken by a few broad ridges, as in the Iguanodon (*fig.* 571.), or grooved by a single longitudinal furrow, as in some serpents (*fig.* 569, A).‡

The cone is longest and its summit sharpest in the serpents: from these may be traced, chiefly in the lizard tribe, a progressive shortening, expansion of the base, and blunting of the apex of the tooth, until the cone is reduced to a hemispherical tubercle, or plate, as in the Thorictes and Cyclodus (*fig.* 570.).

In the Pleiosaur the dental cone is three-sided, with one of the angles rounded off. The posterior subcompressed teeth of the alligator (*fig.* 573.) present a new modification of form; here they terminate in a mammillate summit, supported by a slightly constricted neck. In the tooth of the Hylœosaur the expanded summit is flattened, bent, and spear-shaped, with the edges blunted. But the expansion of the crown is greatest in the subcompressed teeth of the extinct *Cardiodon* and the existing Iguanas, the teeth of which are farther complicated by having the margins notched. The great Iguanodon had the crown of the tooth expanded both in length and breadth, and combining marginal dentations with longitudinal ridges: this tooth (*fig.* 571.) presents the most complicated external form as yet discovered in the class of reptiles.

In no reptiles does the base of the tooth ever branch into fangs.

Attachment.—As a general rule, the teeth of reptiles are anchylosed to the bone which supports them. When they continue distinct, they may be lodged either in a continuous groove, as in the Ichthyosaur §, or in separate sockets, as in the Plesiosaur and Crocodilians (*fig.* 573.). The base of the tooth is anchylosed to the walls of a moderately deep socket in the extinct Megalosaur and Theocodon. In the Labyrinthodonts and Cæciliæ, among the Bratrachians; in most Ophidians; and in the Geckos, Agamians, and Varanians, among the Saurians, the base of the tooth is

* Transactions of the Geological Society, 2d series, vol. vii., 1845, p. 59.

* Odontography, pl. 62 A, *fig.* 4.
† Ib. *fig.* 6 *c.*
‡ Ib. pl. 65; vol. iv., *figs.* 209, 210.
§ Ib. pl. 13, *fig.* 9.

imbedded in a shallow socket, and is confluent therewith.

In the Scincoidians, the Safeguards (*Tejus*), in most Iguanians, in the Chameleons and most other Lacertian reptiles, the tooth is anchylosed by an oblique surface extending from the base more or less upon the outer side of the crown to an external alveolar plate of bone*, the inner alveolar plate not being developed. In the frogs the teeth are similarly but less firmly attached to an external parapet of bone. The lizards which have their teeth thus attached to the side of the jaw are termed Pleurodonts. In a few Iguanians, as the Istiures, the teeth appear to be soldered to the margins of the jaws, these have been termed "Acrodonts." In some large extinct Lacertians, *e. g.* the Mosasaur and Leiodon, the tooth is fixed upon a raised conical process of bone, as shown in my "Odontography," Plate 68. *fig.* 1., and Plate 72. *fig.* 2.

These modifications of the attachment of the teeth of reptiles are closely adapted to the destined application of those instruments, and relate to the habits and food of the species; we may likewise perceive that they offer a close analogy to some of the transitory conditions of the human teeth. There is a period, for example †, when the primitive dental papillæ are not defended by either an outer or an inner alveolar process, any more than their calcified homologues which are confluent with the margin of the jaw in the *Rhynchocephalus*.‡ There is another stage §, in which the groove containing the dental germs is defended by a single external cartilaginous alveolar ridge; this condition is permanently typified in the *Cyclodus* (*fig.* 570.) and most existing lizards. Next there is developed in the human embryo an internal alveolar plate, and the sacs and pulps of the teeth sink into a deep but continuous groove, in which traces of transverse partitions soon make their appearance; in the ancient Ichthyosaur the relation of the jaws to the teeth never advanced beyond this stage.

Finally, the dental groove is divided by complete partitions ||, and a separate socket is formed for each tooth; and this stage of developement is attained in the highest organised reptiles, *e. g.* the crocodiles (*fig.* 573.).

Substance. — This may be four-fold, and a single tooth may be composed of dentine, cement, enamel, and bone; but the dentine and cement are present in the teeth of all reptiles.

In the Batrachians and Ophidians a thin layer of cement invests the central body of dentine, and, as usual, follows any inflections or sinuosities that may characterise the dentine. Besides the outer coat of cement, which is thickest at the base of the teeth, a generally thin coat of enamel defends the crown of the tooth in most Saurians, and the last remains of the pulp are not unfrequently converted into a coarse bone, both in the teeth which are anchylosed to the jaw, and in some teeth, as those of the Ichthyosaur, which remain free. The only modification of the dentine, which could at all entitle it to be regarded in the light of a new or distinct substance, is that which is peculiar in the present class to the teeth of the Iguanodon, and which will be described in the following section.

Structure. — The varieties of dental structure are few in the reptiles as compared with either fishes or mammals, and its most complicated condition arises from interblending of the dentinal and other substances rather than from modifications of the tissues themselves. In the teeth of most reptiles the intimate structure of the dentine corresponds with that which has been described as the type of the tissue, *e.g.* the hard or unvascular dentine, and which is the prevailing modification in Mammalia, viz., the radiation of a system of minute plasmatic tubes from a single pulp-cavity, at right angles to the external surface of the tooth. The most essential modification of this structure is the intermingling of cylindrical processes of the pulp-cavity in the form of medullary canals, with the finer tubular structure.* Another modification is that in which the dentine maintains its normal structure, but is folded inwardly upon itself, so as to produce a deep longitudinal indentation on one side of the tooth; it is the expansion of the bottom of such a longitudinal deep fold that forms the central canal of the venom-fang of the serpent; but a glance at *fig.* 568. will show that, notwithstanding the singularly modified disposition of the dentine (*b*), its structure remains unaltered; and although the pulp-cavity (*p*) is reduced to the form of a crescentic fissure, the dentinal tubes continue to radiate from it according to the usual law. By a similar inflection of many vertical longitudinal folds of the external cement and external surface of the tooth at regular intervals around the entire circumference of the tooth, and by a corresponding extension of radiated processes of the pulp-cavity and dentine into the interspaces of such inflected and converging folds, a modification of dental structure is established in certain extinct reptiles, which, by the various sinuosities of the interblended folds of cement and processes of dentine, with the partial dilatations of the radiated pulp-cavity, produces the complicated structure which is described at p. 868. and figured in cut 552. But this complication is nevertheless referable to a modification of form or arrangement of the dental tissues, rather than of the structure of the tissues themselves: the calcigerous tubes in each sinuous lobe of dentine, in the most

* Odontography, pl. 67.

† At the sixth week of gestation: see Prof. Goodsir, "On the Development of the Human Teeth," Edinburgh Medical and Surgical Journal, No. 138.

‡ See Geological Transactions, 2d series, vol. vii. pt. 2, pl. 6, *figs.* 5 & 6, p. 83.

§ At the seventh or eighth week: Ibid.

|| At the sixth month: Ibid.

* Odontography, pl. 71, Iguanodon.

complex tooth of the Labyrinthodon, exhibit the same general disposition and course as in the fang of the serpent and in the still more simple tooth of the Saurian.

Development.—The teeth of reptiles are never completed, as in certain fishes, at the first or papillary stage; but the pulp sinks into a follicle, and becomes inclosed by a capsule; and in certain reptiles this becomes more or less surrounded by bone; but the process of development never offers the eruptive stage, in the sense in which this is usually understood, as signifying the extrication of the young tooth from a closed alveolus.

The completion of a tooth, with the extinct exception of the Dicynodont Reptiles, is soon followed by preparation for its removal and succession: the faculty of developing new tooth-germs seems to be unlimited in the present class, and the phenomena of dental decadence and replacement are manifested at every period of life; the number of teeth is generally the same in each successive series, and the difference of size presented by the teeth of different and distant series is considerable.

The new germ is always developed, in the first instance, at the side of the base of the old tooth, never in the cavity of the base; the crocodiles form no exception to this rule. The poison-fangs of serpents succeed each other from behind forwards; in almost every other instance the germ of the successional tooth is developed at the inner side of the base of its predecessor. In the frog the dental germ makes its appearance in the form of a papilla developed from the bottom and towards the outer side of a small fissure in the mucous membrane or gum that fills up the shallow groove at the inner side of the alveolar parapet and its adherent teeth: the papilla is soon enveloped by a capsular process of the surrounding membrane: there is a small enamel pulp developed from the capsule opposite the apex of the tooth; the deposition of the earthy salts in this mould is accompanied by ossification of the capsule, which afterwards proceeds *pari passu* with the calcification of the dentinal papilla or pulp; so that, with the exception of its base, the surface of the uncalcified part of the pulp alone remains normally unadherent to the capsule.

As the tooth acquires hardness and size, it presses against the base of the contiguous attached tooth, causes a progressive absorption of that part, and finally undermines, displaces, and replaces its predecessor. The number of nascent matrices of the successional teeth is so great in the frog, and they are crowded so close together, that it is not unusual to find the capsules of contiguous tooth-germs becoming adherent together, as their ossification proceeds. After a brief maceration, the soft gum may be stripped from the shallow alveolar depression, and the younger tooth-germs in different stages of growth are brought away with it.

The mode of development of the teeth of serpents does not differ essentially from that of the teeth of the Batrachian above described except in the relation of the papillæ of the successional poison-fangs to the branch of the poison-duct that traverses the cavity of the loose mucous gum in which they are developed.

Batrachian modifications.—Some of the peculiarities of the dentition of the Batrachians have already been noticed, as in the comparison of the *Siren* with the *Lepidosiren*, in which the true amphibian was shown to have numerous teeth on the palate and lower jaw.*

The piscine character of rasp-like teeth aggregated in numerous series, is manifested also in the Axolotl †, upon the palatal region of the mouth, and upon the splenial or opercular element of the lower jaw; but the superior maxillary bones are here developed, and also support teeth. The premandibular and the premaxillary bones, instead of preserving the larval condition of the horny sheath, have their alveolar border armed with a single row of small, equal, fine and sharp-pointed denticles, which are continued above, along the maxillaries; thus establishing the commencement of the ordinary Batrachian condition of the marginal teeth of the buccal cavity. The dentigerous bones of the palate consist of two plates on each side, as in the *Siren;* the anterior pair, or vomerine bones, converge and meet at their anterior extremities; the minute denticles which they support are arranged quincuncially; the posterior pair of bones are continued backwards according to the usual disposition of the pterygoids, to abut against the tympanic bones; the denticles are confined to the anterior part of their oral surface, and resemble in their arrangement and anchylosed attachment those of the vomerine series, of which they form the posterior termination.

The frogs (*Rana*) ‡ have no teeth on the lower jaw; but in some species the alveolar edge of this bone is finely notched or dentated, as in the horned frogs (*Ceratophrys*). The intermaxillary and maxillary bones support a long, close-set, single series of small, conical, hollow teeth, of which the apices only project beyond the external alveolar ridge to which they are attached. A short transverse row of similar but smaller teeth extends along the posterior border of each vomer, except in the slender-armed frogs (*Leptobrachium*), and in some of the tree frogs (e. g. *Euchnemis*), in which the roof of the mouth is edentulous.

Amongst the most extraordinary examples of extinct reptiles are those which are characterised by the labyrinthic modification of the dental structure above described, and which with some affinities to Saurians, combine characters which are essentially those of the order *Batrachia.* I have ascertained by fossil portions of the upper jaw of the *Labyrinthodon leptognathus* that the maxillary or facial division of the skull was broad, much depressed, and flattened, resembling the skull of the

* Odontography, pl. 62, *figs.* 5 & 6
† Ib. pl. 62, *fig.* 4.
‡ Ib. pl. 62, *fig.* 10.

gigantic Salamander and of the Alligator; and the outer surface of the bones was strongly sculptured, as in the Crocodilian family, but of a relatively larger and coarser pattern. The upper jaw contains a single row of small teeth, about sixty in number, anterior to which are three or four large conical tusks. The bases of the serial teeth project directly from the outer wall of the shallow socket, there being no alveolar ridge external to it. The second large anterior tusk is three times the size of the first of the serial teeth, and the size of these teeth gradually diminishes as they are placed further back; the length of the common-sized teeth being about two lines, and the greatest breadth one-third of a line. The apical two-thirds of each tooth is smooth, but the basal third is fluted and anchylosed to the outer wall of the socket. The osseous roof of the mouth is principally composed of a pair of broad and flat bones, homologous with the divided vomer in *Batrachia*, but of much greater relative extent, approaching, in this respect, those of the Menopome, and defending the mouth with a more extensive roof of bone than exists in any Lacertian reptile; physiologically, therefore, the *Labyrinthodon*, in this part of its structure, comes nearest to the Crocodile; but the structure itself, morphologically, is essentially Batrachian.* In the Menopome† and gigantic Salamander, a row of small teeth extends transversely across the anterior extremity of the vomerine bones; and the occurrence in the *Labyrinthodon* of a similar row, consisting in each palatine bone of three median small teeth and two outer larger ones, marks most strongly its Batrachian nature; and from the outermost tooth a longitudinal row of small and equal-sized teeth is continued backward along the exterior margin of the palatine bone. The whole of this series of palatal teeth is nearly concentric with the maxillary teeth.

In Lacertine reptiles the examples of a row of palatal teeth are rare, and, when present, it is short, and situated towards the back of the palate, upon the pterygoid bones, as in the Iguana and Mosasaur.‡ In Batrachians the most common disposition of the palatal teeth is a transverse row placed at the anterior part of the divided vomer, as in Frogs, the Menopome and gigantic Salamander, and at the posterior part in certain toads. In the Amphiume, on the contrary, the palatal teeth form a nearly longitudinal series along the outer margin of the palatine bones. The *Labyrinthodon* combines both these dispositions of the palatal teeth. The lower jaw, like the upper, contains a series of small teeth, with a few larger tusks anterior to them, the serial teeth are long and slender, gradually diminishing in size towards the anterior portion of the jaw; the largest fossil portion which I have obtained presents a linear series of not less than fifty sockets, placed alternately, one nearer the inner, the next nearer the outer side of the jaw. The sockets of the teeth are shallower than in the upper jaw; the outer wall is more developed than the inner, and the anchylosed bases of the teeth more nearly resemble, in their oblique position, those of existing *Batrachia*. With regard to the modification of the microscopic structure of the teeth, I may observe that, between the apex and the part where the inflected vertical folds of the cement commence, the tooth resembles, in the simplicity of its intimate structure, that of the entire tooth of ordinary *Batrachia* and most reptiles; and in the lower or basal half of the tooth the labyrinthic structure above described commences, and gradually increases in complexity.

* Odontography, pl. 63. A, *fig.* 3.
† Ib. pl. 62. *figs.* 1 & 2.
‡ Ib. pl. 68.

In the genus *Deirodon**, the teeth of the ordinary bones of the mouth are so small as to be scarcely perceptible; and they appear to be soon lost, so that it has been described as edentulous, and has been called "Anodon." An acquaintance with the habits and food of this species has shown how admirably this apparent defect is adapted to its well-being. Its business is to restrain the undue increase of the smaller birds by devouring their eggs. Now if the teeth had existed of the ordinary form and proportions in the maxillary and palatal regions, the egg would have been broken as soon as it was seized, and much of the nutritious contents would have escaped from the lipless mouth of the snake in the act of deglutition; but, owing to the almost edentulous state of the jaws, the egg glides along the expanded opening unbroken; and it is not until it has reached the gullet, and the closed mouth prevents any escape of the nutritious matter, that the egg becomes exposed to instruments adapted for its perforation. These instruments consist of the inferior spinous pocessess (hypapophyses) of the seven or eight posterior cervical vertebræ, the extremities of which are capped by a layer of hard cement, and penetrate the dorsal parietes of the œsophagus. They may be readily seen, even in very small subjects, in the interior of that tube, in which their points are directed backwards. The shell being sawed open longitudinally by these vertebral teeth, the egg is crushed by the contractions of the gullet, and is carried to the stomach, where the shell is no doubt soon dissolved by the acid gastric juice.

In the *Boa Constrictor*, the teeth are slender, conical, suddenly bent backwards and inwards above their base of attachment; the crown is straight or very slightly curved, *e. g.* in the posterior teeth. The intermaxillary bone supports four small teeth; each maxillary bone has eight much larger ones, which gradually decrease in size as they are placed further back. There are eight or nine teeth of similar size and proportions in each premandibular bone. These teeth

* The *Coluber scaber* of Linnæus; an arboreal serpent of South Africa.

are separated by wide intervals, from which other teeth, similar to those in place, have been detached. The base of each of the above teeth is extended transversely, compressed antero-posteriorly, and anchylosed to a shallow alveolus, extending obliquely across the shallower alveolar groove. An affinity to the lizard tribes is manifested by the greater development of the outer, as compared with the inner wall of the alveolar furrow.

The palatine teeth, of which there are three or four in each palatal bone, are as large as the superior maxillary, and are similarly attached. The pterygoid teeth, five or six in number, which complete the internal dental series on the roof of the mouth, are of smaller size, and gradually diminish as they recede backwards. In the interspaces of the fixed teeth in both these bones, the places of attachment of the shed teeth are always visible; so that the dental formula, if it included the vacated with the occupied sockets, would express a greater number of teeth than are ever in place and use at the same time.* In the smaller species of Boa, the intermaxillary bone is edentulous.

The *Colubers*, like other true serpents, have two longitudinal rows of teeth on the roof of the mouth, extending along the palatines and pterygoids. The genus *Oligodon* appears to form the sole exception to this rule. In the *Dryinus nasutus*, a few small teeth are present on the ecto-pterygoid as well as on the pterygoid.

In certain genera of non-poisonous serpents, as *Dryophis*, *Dipsas*, and *Bucephalus*, in which the superior maxillary teeth increase in size towards the posterior part of the bone, the large terminal teeth of the series are traversed along their anterior and convex side by a longitudinal groove. In the *Bucephalus capensis*, the two or three posterior maxillary teeth present this structure, and are much larger than the anterior teeth, or those of the palatine and premandibular series. They add materially, therefore, to the power of retaining the prey, and may conduct into the wounds which they inflict an acrid saliva; but they are not in connection with the duct of an express poison-gland. The long-grooved fangs are either firmly fixed to the maxillary bones, or are slightly moveable, according to their period of growth. They are concealed by a sheath of thick and soft gum, and their points are directed backwards. The sheath always contains loose recumbent grooved teeth, ready to succeed those in place.

In most of the *Colubri*, each maxillary and premandibular bone includes from twenty to twenty-five teeth. They are less numerous in the genera *Tortrix* and *Homalopsis*, and are reduced to a still smaller number in the poisonous serpents, in the typical genera of which the short maxillary bone supports only a single perforated fang.

* Odontography, pl. 65, *figs.* 6 & 7.

Poisonous Serpents. — The transition to these serpents, which was begun in the *Bucephali* and allied genera with grooved maxillary teeth, is completed by the poisonous serpents of the genera *Pelamis*, *Hydrophis*, *Elaps*, *Bongarus*, and *Hamadryas*.

The superior maxillary bone diminishes in length with the decreasing number of teeth which it supports. The ecto-pterygoid bone elongates in the same ratio, so as to retain its position as an abutment against the shortened maxillary, and the muscles implanted into this external pterygoid bone communicate through it to the maxillary bone the hinge-like movements backwards and forwards upon the ginglymoid articulations connecting that bone with the prefrontal and palatine bones. As the fully-developed poison-fangs are attached by the same firm basal anchylosis to maxillary sockets, which forms the characteristic mode of attachment of the simple or solid teeth, they necessarily follow all the movements of the superior maxillary bone. When the external pterygoid is retracted, the superior maxillary rotates backwards, and the poison-fang is concealed in the lax mucous gum, with its point turned backwards. When the muscles draw forward the external pterygoid, the superior maxillary bone is pushed forwards, and the recumbent fang withdrawn from its concealment and erected.

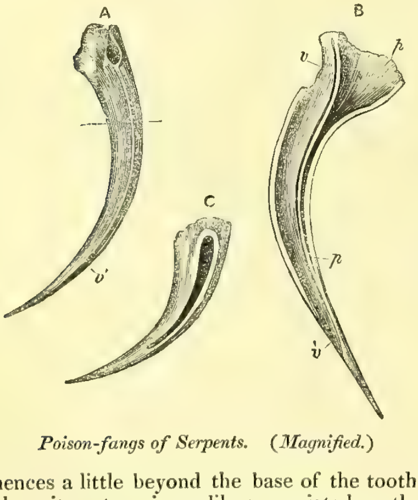
In this power of changing the direction of a large tooth, so that it may not impede the passage of food through the mouth, we may perceive an analogy between the viper and the Lophius; but in the fish the movement is confined to the tooth alone, and is dependent on the mere physical property of the elastic medium of attachment; in the serpent the tooth has no independent motion, but rotates with the jaw, whose movements are governed by muscular actions. In the fish the great teeth are erect, except when pressed down by some extraneous force. In the serpent the habitual position of the fang is the recumbent one, and its erection takes place only when the envenomed blow is to be struck.

A true idea of the structure of a poison-fang will be formed by supposing the crown of a simple tooth, as that of a boa, to be pressed flat, and its edges to be then bent towards each other, and soldered together so as to form a hollow cylinder, or rather cone, open at both ends. The flattening of the fang and its inflection around the poison-duct commences immediately above the base, and the suture of the inflected margins runs along the anterior and convex side of the recurved fang, as shown in *fig.* 567, A.: the poison-canal is thus in front of the pulp-cavity, as shown in the longitudinal section of the fang B. The basal aperture of the poison-canal v is oblique, and its opposite outlet v' is still more so, presenting the form of a narrow elliptical longitudinal fissure terminating at a short distance from the apex of the fang. The relative position of the two apertures of the poison-canal is shown in the figure of the fang of the large Cobra in my "Odontography" (pl. 65. *fig.* 9., and in Vol. IV. p. 290. *fig.* 210., art. Reptilia), where a fine hair is represented as passing through the poison-canal.

The poison-glands occupy the sides of the posterior half of the head; each gland consists of a number of elongated narrow lobes, extending from the main duct, which runs along the lower border of the gland upwards and slightly backwards: each lobe gives off lobules throughout its extent, thus presenting a pinnatifid structure; and each lobule is subdivided into smaller secerning cæca, which constitute the ultimate structure of the gland. The whole gland is surrounded by a double aponeurotic capsule, of which the outermost and strongest layer is in connection with the muscles by whose contraction the several cæca and lobes of the gland are compressed and emptied of their secretion. This is then conveyed by the duct (see Reptilia, Vol. IV. p. 291., *fig.* 211. *e*) to the basal aperture of the poison-canal of the fang *f.* We may suppose, that as the analogous lachrymal and salivary glands in other animals are most active during particular emotions, so the rage which stimulates the venom-snake to use its deadly weapon must be accompanied with an increased secretion and great distension of the poison-glands; and as the action of the compressing muscles is contemporaneous with the blow by which the serpent inflicts the wound, the poison is at the same moment injected with force into the wound from the apical outlet of the perforated fang.

The duct which conveys the poison, although it runs through the centre of a great part of the tooth, is really on the outside of the tooth, the canal in which it is lodged and protected being formed by a longitudinal inflection of the dentinal parietes of the pulp-cavity. This inflection com-

Fig. 567.

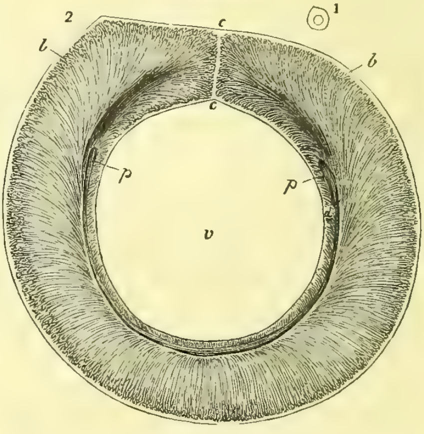


Poison-fangs of Serpents. (*Magnified.*)

mences a little beyond the base of the tooth, where its nature is readily appreciated, as the poison-duct there rests in a slight groove or longitudinal indentation on the convex side of the fang; as it proceeds it sinks deeper into the substance of the tooth, and the sides of the groove meet and seem to coalesce, so that the trace of the inflected fold ceases, in some species, to be perceptible to the naked eye; and the fang appears, as it is commonly described, to be perforated by the duct of the poison-gland. In the *Hydrophis* the groove remains permanently open, as in *fig* 567. c.

From the real nature of the poison-canal it follows that the transverse section of the tooth varies in form in different parts of the tooth; at the base it is oblong, with a large pulp-cavity of a corresponding form, with an entering notch at the anterior surface; farther on the transverse section presents the form of a horse-shoe, and the pulp-cavity that of a crescent, the horns of which extend into the sides of the deep cavity of the poison-fang: a little beyond this part the section of the tooth itself is crescentic, with the horns obtuse and in contact, so as to circumscribe the poison-canal; and along the whole of the middle four-sixths of the tooth, the section, of which a magnified view is given in *fig.* 568.,

Fig. 568.



Section of poison-fang of Serpent. (*Magnified.*)

shows the dentine of the fang inclosing the poison-canal, and having its own centre or pulp-canal (p, p), in the form of a crescentic fissure, situated close to the concave border of the inflected surface of the tooth. The pulp-cavity disappears, and the poison-canal again resumes the form of a groove near the apex of the fang, and terminates on the anterior surface in an elongated fissure.

The venom-fangs of the viper, rattle-snake, and the *Fer-de-lance* are coated only with a thin layer of a subtransparent and minutely cellular cement. The disposition of the dentinal tubes is obedient to the general law of verticality to the external surface of the tooth; it is represented as seen in the transverse section from the middle of the fang in *fig.* 568. Since the inflected surface of the tooth can be exposed to no other pressure than that of the turgescent duct with which it is in contact, the tubes which proceed to the surface *d*, while maintaining their normal relation of the right angle to it, are extremely short; and the layer of dentine separating the poison-tube from the pulp-cavity is proportionally thin. The calcigerous tubes that radiate from the opposite side of the pulp-cavity to the exposed surface *b* of the tooth are disproportionally long.

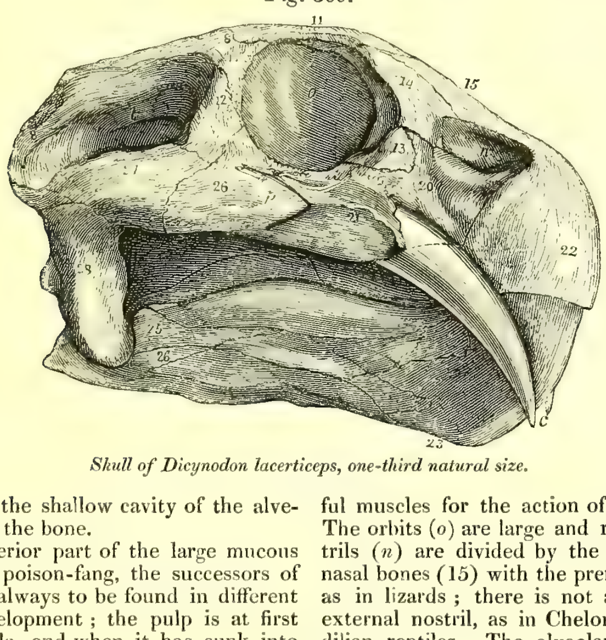
The teeth of Ophidians are developed and completed in that part which forms the original seat of the tooth-germs in all animals; viz. the mucous membrane or gum covering, the alveolar border of the dentigerous bones. This germ presents the same lax tissue, and is as abundantly developed, as in the Pike, Lophius, and many other fishes; in which it likewise serves as the nidus and locality for the complete development of the teeth. The primitive dental papillæ in the common harmless snake very soon sinks into the substance of the gum, and becomes inclosed by a capsule. As soon as the deposition of the calcareous salts commences in the apex of the papilla the capsule covering that part becomes ossified and adherent to the dentine, and the tooth begins to pierce and emerge from the gum before its mould, the pulp, is half completed. Fresh layers of cells are successively added to the base of the pulp, and converted, by their confluence and calcification, into the tubular dentine, until the full size of the tooth is attained, when its situation in the gum is gradually changed, and its base becomes anchylosed to the shallow cavity of the alveolar surface of the bone.

In the posterior part of the large mucous sheath of the poison-fang, the successors of this tooth are always to be found in different stages of development; the pulp is at first a simple papilla, and when it has sunk into the gum the succeeding portion presents a depression along its inferior surface, as it lies horizontally, with the apex directed backwards; the capsule adheres to this inflected surface of the pulp; and the base of the groove of the loose, growing, poison-fang is brought into the same relation with the duct of the poison gland as the displaced fang, which has been severed from the duct.

Saurians. — The existing species of lizards differ from those of the crocodile in the anchylosed condition of the teeth, which present few modifications of importance; those that yield most fruit to physiology, and which have most expanded our ideas of the extent of the resources of Nature and the exceptional deviations from what was deemed the rule of structure in the Saurian dentition, have been discovered by the study of the fossil teeth of extinct forms of the order. Amongst these the most extraordinary in respect of their dental system have been recently discovered in a formation in South Africa, which seems nearly as ancient as our own coal-seams. I have called them "Dicynodonts,"* from their dentition being reduced to one long and large canine tooth on each side of the upper jaw. As these teeth give, at first sight, a character to the jaws like that which the long poison-fangs give, when erected, to the jaws of the rattlesnake, I shall briefly notice their characters before entering upon the description of the more normal Saurian dentition.

Fig. 569. gives a reduced side view of the skull of the species of *Dicynodon* called *D. lacerticeps*. The cranial cavity (8, 8) is extremely contracted, as in all the cold-blooded quadrupeds: it is bounded on each side by wide and deep temporal fossæ (*t*) indicating powerful muscles for the action of the lower jaw. The orbits (*o*) are large and round; the nostrils (*n*) are divided by the junction of the nasal bones (15) with the premaxillaries (22), as in lizards; there is not a single median external nostril, as in Chelonian and Crocodilian reptiles. The alveolar border of the lower jaw and of the premaxillary part of the

Fig. 569.



Skull of Dicynodon lacerticeps, one-third natural size.

* From δὶς, two, and κυνόδους, the name given by Hippocrates to the *canine teeth*, and signifying the same idea as their common English denomination.

upper jaw is trenchant, and seems to have been sheathed with horn.

The maxillary bone (21) is excavated by a wide and deep alveolus, with a circular area of half an inch, and lodges a long and strong, slightly curved, and sharp-pointed, canine tooth or tusk, which projects about two-thirds of its length from the open extremity of the socket. The direction of the tusks is forwards, downwards, and very slightly inwards; the two converging, as they descend along the outer side of the compressed symphysis of the lower jaw (*c*). The tusk is principally composed of a body of compact unvascular dentine. The base is excavated by a wide conical pulp-cavity (*p*) with the apex extending to about one-half of the implanted part of the tusk, and a linear tract is continued along the centre of the solid part of the tusk. From this central line the dentinal tubes radiate, with a gentle curve at the beginning, convex towards the point of the tusk, and then proceeding straight to the periphery of the tooth, but inclining towards the apex. They present parallel secondary curves, divide dichotomously twice or thrice near their beginning, and send off numerous small lateral branches, chiefly from the side next the apex. At their primary curve the dentinal tubes are $\frac{1}{12000}$th of an inch in diameter, and their intervals are $\frac{1}{6000}$th of an inch across. The dentinal cells are most conspicuous near the periphery of the tooth, and vary in diameter from $\frac{1}{800}$th to $\frac{1}{1000}$th of an inch.

The enamel, at least at the middle of the tusk, is thinner than in the teeth of the crocodile. It presents only a finely lamellated texture, the layers being parallel with the surface of the dentine on which it rests. There is only a fine linear trace of cement on the exterior of the sections of the implanted base of the tusks; and here it is too thin to allow of the development of the radiated cells in its substance. There is no trace of teeth or their sockets in the lower jaw (25, 23); so much of the alveolar border as is exposed presents a smooth and even edge, which seems to have played like a scissor-blade upon the inner side of the corresponding edentulous border of the upper jaw; and it is most probable, from the analogies of similarly-shaped jaws of existing Reptilia, that the fore part of both the upper and under jaws were sheathed with horn.

Until the discovery of the *Rhynchosaurus**, this edentulous and horn-sheathed condition of the jaws was supposed to be peculiar to the Chelonian order among reptiles; and it is not one of the least interesting features of the Dicynodonts of the African sandstones, that they should repeat a Chelonian character, hitherto peculiar, amongst Lacertians, to the above-cited remarkable extinct edentulous genus of the new red sandstone of Shropshire: but our interest rises almost to astonishment, when, in a Saurian skull, we find, superadded to the horn-clad mandibles of the Tortoise, a pair of tusks, borrowed as it were from the mammalian class, or rather foreshadowing a structure which, in the actual creation, is peculiar to certain members of the highest organised warm-blooded animals.

* Transactions of the Cambridge Philosophical Society, vol. vii. part iii.

In the other Reptilia, recent or extinct, which most nearly approach the Mammalia in the structure of their teeth, the difference characteristic of the inferior and cold-blooded class is manifested in the shape, and in the system of shedding and succession, of the teeth: the base of the implanted teeth seldom becomes consolidated, never contracted to a point, as in the fangs of the simple teeth of Mammalia, and at all periods of growth one or more germs of teeth are formed within or near the base of the tooth in use, prepared to succeed it, and progressing towards its displacement. The dental armature of the jaws is kept in serviceable order by uninterrupted change and succession; but the matrix of the individual tooth is soon exhausted, and the life of the tooth itself may be said to be comparatively short.

The Dicynodonts not only manifest the higher type of free implantation of the base of the tooth in a deep and complete socket, common to Crocodilians, Megalosaurs, and Thecodonts, but make an additional and much more important step towards the mammalian type of dentition, by maintaining the serviceable state of the tusk by virtue of constant renovation of the substance of one and the same matrix, accordingly to the principle manifested in the long-lived and ever-growing tusks of the Walrus, and the scalpriform incisors of the Rodentia.

The genera of the typical family of the squamate Lacertians are arranged in two sub-families, the chief characteristics of which are derived from the dental system.

In the first group, the teeth are solid, or without any permanent internal cavity, and are very firmly anchylosed by their base to the alveolar groove upon the inner side of the jaw; so that the extremity of the tooth is slightly directed outwards. The species which present this character are called Pleodonts.

In the second group, the teeth are excavated, or retain the pulp-cavity, and are less firmly fixed to the jaws, being applied vertically, like piles or buttresses, against the outer alveolar parapet, but not adhering by their base. This group is called Cœlodonts.

The Monitor Lizard of S. America is an example of the Pleodont group, in which the premaxillary teeth are ten in number. The maxillary teeth vary from ten to fifteen on each side, and increase in size as they are placed farther back: the hindmost teeth are tricuspid in young individuals, and present the form of simple tubercles in the old Monitors. The mandibular teeth, fifteen to eighteen in number in each ramus, correspond in size and form with those above. In the Cœlodont group, the "Swift lizards" (*Tachydromus*) have the pterygoid bones armed with minute teeth. The teeth on both upper and lower jaws are of larger size, and the hinder ones are tricuspid. The true lizards (*Lacerta*) have two kinds of teeth *quoad* form; the anterior small, conical, and recurved; the posterior larger, and bi- or tri-cuspid. Some species have also pterygoid teeth; as the common *Lacerta agilis*.

In the Gigantic fossil Monitor of Maestricht, the teeth combine the Pleodont with the Acrodont* characters.

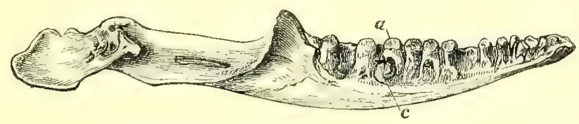
The true affinities of the Mosasaur, which was at least twenty-four feet in length, and the remains of which characterise the chalk-formations, were first determined by Cuvier, who places it in the Lacertian group of Saurians, between the Iguanæ and Monitors. Its dentition exhibits in an eminent degree the Acrodont character; the teeth being supported on expanded conical bases anchylosed to the summit of the alveolar ridge of the jaw: no existing Saurian exactly parallels this mode of attachment of the teeth, either in regard to the breadth of the alveolar border, or in the relative size of the osseous cones to the teeth which they support. A shallow socket is left where the tooth and its supporting base are shed. The form of the teeth is likewise different from that hitherto observed in any existing Saurian: the crown is pyramidal, with the outer side nearly plane, or slightly convex, and separated by two sharp ridges from the remaining surface, which forms a half-cone. All the teeth are slightly recurved, and their peripheral surface is smooth. The teeth are implanted upon the premaxillary, maxillary, and premandibulary bones; a series of similarly shaped but much smaller teeth are placed upon the pterygoid bones.

The gradual transition from the simple structure of the compact dentine to the osteodentine of the anchylosed base of the tooth was not known to Cuvier; otherwise he could not have supposed that the crown and the base of the tooth of the Mosasaurus were formed by vital processes of so dissimilar a nature as to forbid him considering them as parts of one and the same body. Cuvier had originally described the expanded base of the tooth of the Mosasaur as the root of the tooth; but afterwards, observing that the corresponding base became anchylosed by ossification of the remains of the pulp to the jaw, he conceived it to be incorrect to regard it as a part of a body which he believed to be an inorganic product, and the result of excretion. "The tooth," he observes, in correcting his first account of the Mosasaurus, "has no true root, but it adheres strongly to that pulp which has secreted it, and it is further held in connection with it by the remains of the capsule which has furnished the enamel, and which, by becoming ossified also, and uniting itself to the maxillary bone and the ossified pulp, implants or rivets the tooth with additional force."

The necessity under which Cuvier felt himself compelled to regard the crown and the base of the tooth of the Mosasaur as two distinct parts, is at once banished by the recognition of the principle, that the processes of calcification are essentially the same at every part of a tooth, whether it be free or anchylosed; and that they are modified only, as I have shown in my Memoir on the Formation of the Teeth of the Shark*, according to the density of the part to be produced.

Scincoid Lizards.—Most of these smooth-scaled lizards have small mouths and slender sharp teeth, fitted best for insect food; they are usually confined to the upper and lower jaws; but the medicinal Scink of ancient pharmacy (*Scincus officinalis*) has four or five small obtuse teeth upon each pterygoid bone. The chief exception to the typical dentition of the present family is made by the large scincoid lizards of Australia, which, on that account, have received the generic name of *Cyclodus*.†

Fig. 570.



Lower jaw and teeth of Cyclodus nigroluteus.

The dentition of the *Cycl. nigroluteus* is exemplified in the lower jaw, *fig*. 570. In the upper jaw, the single premaxillary bone has depressions for twelve teeth, of which only the alternate ones are usually in place; they are of very small size, with the fang compressed laterally, and the crown antero-posteriorly, so as to resemble a true incisor in form, the summit sloping to an edge from behind forwards, with the middle of the cutting surface a little produced. Each superior maxillary bone has depressions for fourteen teeth; they quickly increase in size, and exchange their conical for a sub-hemispherical crown; the eighth to the thirteenth inclusive are the largest teeth; they are set obliquely, and pretty close together. In the lower jaw there are two small incisors, at the anterior part of each premandibular bone corresponding with those of the premaxillary; these are succeeded by five or six conical teeth, and the rest correspond in size and form with the tuberculate molars of the upper jaw.

* Odontography, pp. 241. 258.

* Compte Rendu de l'Académie des Sciences, Decembre, 1839.

† Round-toothed: κυκλος, round; οδους, tooth.

All the teeth are attached, after the Pleurodont type, by their base and outer margin to shallow depressions on the outer side of the external alveolar parapet.

The germs of the successional teeth, *c. fig.* 570., are developed at the inner side of the base of their predecessors, *a*, which they excavate, undermine, and displace in the usual manner.

Iguanas.—Certain genera of this family of lizards, e. g. *Istiurus*, *Lophyrus*, *Calotes*, and *Otocryptis*, have the teeth soldered, like those of *Mosasaurus*, to the summit of the alveolar ridge, and thence are called "Acrodonts:" in all these lizards the maxillary and mandibular teeth may be divided into anterior laniary, and posterior molary teeth. In most of the Iguanians the teeth are lodged in a common shallow oblique alveolar groove, and are soldered to excavations on the inner surface of the outer wall of the groove: these are called Pleurodonts. Most of them possess pterygoid as well as maxillary teeth: but the following genera, *Hyperanodon*, *Tropidolepis*, *Phrynosoma*, and *Callisaurus*, are exceptions.

In the Pleurodont Iguanians, the teeth never present the true laniary form; and if simply conical, as at the extremes of the maxillary series, the cone is more or less obtuse; but, in general, it is expanded, more or less trilobate, or dentated along the margin of the crown.

The *Amblyrhynchus*, a genus which is somewhat remarkable for the marine habits of at least one of the species (*Amblyrhynchus ater*), whose diet is sea-weed*, has the tricuspid structure well developed in the posterior teeth.

The typical genus of the present family of Saurians (*Iguana tuberculata*), is characterised by the crenate or dentated margin of the crown of the maxillary and premandibular teeth, a few of the anterior small ones excepted. The pterygoid teeth are arranged in two or three irregular rows, resembling somewhat the "dents en cardes" of fishes. In the full-grown *Iguana tuberculata* there are from forty-seven to forty-nine teeth in both upper and lower jaws. The number is less in young subjects. The double row of pterygoid teeth are in close order on each side.

In the horned Iguana (*Metopoceros cornutus*), there are about fifty-six teeth in the upper and lower jaws, of which the four first are conical and slightly recurved. The twelve succeeding teeth are somewhat larger in size, with more compressed and expanded crowns; the rest are triangular, compressed, with dentated margins. The inner surface of the crown of the tooth is simply convex and smooth; the outer surface traversed by a median, longitudinal, broad, obtuse ridge. There is a single row of small teeth implanted in each pterygoid bone. No Iguanian lizard has teeth on the palatine bones.

The teeth of the *Iguanodon*, though resembling those of the Iguana, do not present an exact magnified image of them, but differ in the greater relative thickness of the crown, its more complicated external surface, and, still more essentially, in a modification of the internal structure, by which the *Iguanodon* equally deviates from every other known reptile.

As in the Iguana, the base of the tooth is elongated, contracted, and subcylindrical; the crown expanded, and smoothly convex on the inner side. When first formed, it is acuminated, compressed, its sloping sides serrated, and its external surface traversed by a median longitudinal ridge, and coated by a layer of enamel, but, beyond this point, the description of the tooth of the Iguanodon indicates characters peculiar to that genus. In most of the teeth that have hitherto been found, three longitudinal ridges (*fig.* 571.) traverse the outer surface of the crown, one on each side of the median primitive ridge; these are separated from each other, and from the serrated margins of the crown, by four wide and smooth longitudinal grooves. The relative width of these grooves varies in different teeth; sometimes a fourth small longitudinal ridge is developed on the outer side of the crown. The marginal serrations, which, at first sight, appear to be simple notches, as in the Iguana, present, under a low magnifying power, the form of transverse ridges, themselves notched, so as to resemble the mammilated margins of the unworn plates of the elephant's grinder: slight grooves lead from the interspaces of these notches upon the sides of the marginal ridges. These ridges, or dentations, do not extend beyond the expanded part of the crown: the longitudinal ridges are continued further down, especially the median ones, which do not subside till the fang of the tooth begins to assume its subcylindrical form. The tooth at first increases both in breadth and thickness; it then diminishes in breadth, but its thickness goes on increasing; in the larger and fully formed teeth, the fang de-

Fig. 571.

Unworn tooth of Iguanodon.

* This species, and probably all the known *Amblyrhynchi*, or blunt-nosed Iguanæ, inhabit the islands in the Galopagos group; their habits have been well elucidated by Mr. Darwin (Voyage of the Beagle, vol. iii. p. 466.). In specimens which he dissected, he found the stomach loaded with minced sea-weed.

creases in every diameter, and sometimes tapers almost to a point. The smooth unbroken surface of such fangs indicates that they did not adhere to the inner side of the maxillæ, as in the Iguana, but were placed in separate alveoli, as in the Crocodile and Megalosaur; such support would appear, indeed, to be indispensable to teeth so worn by mastication as those of the Iguanodon. A fracture of this tooth shows that the pulp was not entirely solidified, but that its cavity had continued open at the thickest part of the tooth.

The apex of the tooth soon begins to be worn away, and it would appear, by many specimens that have been found, that the teeth were retained until nearly the whole of the crown had yielded to the daily abrasion. In these teeth, however, the deep excavation of the remaining fang, represented in profile in the figure *fig.* 571., plainly bespeaks the progress of the successional tooth prepared to supply the place of the worn-out grinder.

At the earlier stages of abrasion, a sharp edge is maintained at the external part of the tooth by means of the enamel which covers that surface of the crown. The prominent ridges upon that surface give a sinuous contour to the middle of the cutting edge, whilst its sides are jagged by the lateral serrations. The adaptation of this admirable dental instrument to the cropping and comminution of such tough vegetable food as the *Clathrariæ* and similar plants, which are found buried with the Iguanodon, is pointed out by Dr. Buckland, with his usual felicity of illustration, in his "Bridgewater Treatise," vol. i. p. 246.

When the crown is worn away beyond the enamel, it presents a broad and nearly horizontal grinding surface, and now another dental substance is brought into use to give an inequality to that surface; this is the ossified remnant of the pulp, which, being firmer than the surrounding dentine, forms a slight transverse ridge in the middle of the grinding surface. The tooth in this stage has exchanged the functions of an incisor for that of a molar, and is prepared to give the final compression, or comminution, to the coarsely divided vegetable matters.

The marginal edge of the incisive condition of the tooth and the median ridge of the molar stage are more effectually established by the introduction of a modification into the texture of the dentine, by which it is rendered softer than in the existing Iguanæ and other reptiles, and more easily worn away: this is effected by an arrest of the calcifying process along certain cylindrical tracts of the pulp, which is thus continued, in the form of medullary canals, analogous to those in the soft dentine of the Megatherium's grinder, from the central cavity, at pretty regular intervals, parallel with the calcigerous tubes, nearly to the surface of the tooth. The medullary canals radiate from the internal and lateral sides of the pulp-cavity, and are confined to the dentine forming the corresponding walls of the tooth; their diameter is $\frac{1}{1250}$th of an inch; they are separated by pretty regular intervals, equal to from six to eight of their own diameters; they sometimes divide once in their course. Each medullary canal is surrounded by a clear substance; its cavity was occupied in the section described by a substance of a deeper yellow colour than the rest of the dentine.

The calcigerous tubes present a diameter of $\frac{1}{25,000}$th of an inch, with interspaces equal to about four of their diameters. At the first part of their course, near the pulp-cavity, they are bent in strong undulations, but afterwards proceed in slight and regular primary curves, or in nearly straight lines, to the periphery of the tooth. When viewed in a longitudinal section of the tooth, the concavity of the primary curvature is turned towards the base of the tooth; the lowest tubes are inclined towards the root, the rest have a general direction at right angles to the axis of the tooth; the few calcigerous tubes, which proceed vertically to the apex, are soon worn away, and can be seen only in a section of the apical part of the crown of an incompletely developed tooth. The secondary undulations of each tooth are regular and very minute. The branches, both primary and secondary, of the calcigerous tubes are sent off from the concave side of the main inflections; the minute secondary branches are remarkable at certain parts of the tooth for their flexuous ramifications, anastomoses, and dilatations into minute calcigerous cells, which take place along nearly parallel lines for a limited extent of the course of the main tubes. The appearance of interruption in the course of the calcigerous tubes, occasioned by this modification of their secondary branches, is represented by the irregularly dotted tracts in the figure of the dental structure of this ancient reptile given in my "Odontography." This modification must contribute, with the medullary canals, though in a minor degree, in producing that inequality of texture and of density in the dentine, which renders the broad and thick tooth of the Iguanodon more efficient as a triturating instrument.

The enamel which invests the harder dentine, forming the outer side of the tooth, presents the same peculiar dirty brown colour, when viewed by transmitted light, as in most other teeth: very minute and scarcely perceptible undulating fibres, running vertically to the surface of the tooth, is the only structure I have been able to detect in it.

The cement is simply and minutely cellular upon the crown of the tooth, but it exhibits the radiated cells at the base of the tooth.

The remains of the pulp in the contracted cavity of the completely formed tooth are converted into a dense but true osseous substance, characterised by minute elliptical radiated cells, whose long axis is parallel with the plane of the concentric lamellæ, which surround the few and contracted medullary canals in this substance.

The microscopical examination of the structure of the Iguanodon's teeth thus contributes additional evidence of the perfection of their adaptation to the offices to which their more obvious characters had indicated them to have been destined.

To preserve a trenchant edge, a partial coating of enamel is applied; and, that the thick body of the tooth might be worn away in a more regularly oblique plane, the dentine is rendered softer as it recedes from the enameled edge by the simple contrivance of arresting the calcifying process along certain tracts of the inner wall of the tooth. When attrition has at length exhausted the enamel and the tooth is limited to its functions as a grinder, a third substance has been prepared in the ossified remnant of the pulp to add to the efficiency of the dental instrument in its final capacity. And if the following reflections were natural and just after a review of the external characters of the dental organs of the Iguanodon, their truth and beauty become still more manifest as our knowledge of their subject becomes more particular and exact:

"In this curious piece of animal mechanism we find a varied adjustment of all parts and proportions of the tooth, to the exercise of peculiar functions, attended by compensations adapted to shifting conditions of the instrument, during different stages of its consumption. And we must estimate the works of nature by a different standard from that which we apply to the productions of human art, if we can view such examples of mechanical contrivance, united with so much economy of expenditure, and with such anticipated adaptations to varying conditions in their application, without feeling a profound conviction that all this adjustment has resulted from design and high intelligence."*

Varanians.—In the great Crocodilian Monitor (*Varanus crocodilinus*), the large fixed compressed teeth, of which there may be about seven in each upper maxillary bone and six in each premandibular, are anchylosed by the whole of their base and by an oblique surface leading upwards on the outer side of the tooth to a slight depression on the oblique alveolar surface, as in the *Var. striatus*. The base of the tooth is finely striated, the lines being produced by inflected folds of the external cement, as in the Ichthyosaur and Labyrinthodon, but they are short and straight, as in those of the former genus. The alveolar channel or groove has scarcely any depth; but the anchylosed base of the tooth is applied to an oblique surface, terminating in a sharp edge, from which the outer side of the free crown of the tooth is directly continued. The great *Varanus*, like the variegated species manifests its affinity to the Crocodilians in the number of successive teeth which are in progress of growth to replace each other; but from the position in which the germs of the successional teeth are developed, the more advanced teeth in this species, as in the *Var. variegatus*, do not exhibit the excavations that characterise the same parts of the teeth of the Enaliosaurs and Crocodiles.

Thecodonts.—We have seen that among the inferior or squamate Saurians there are two leading modifications in the mode of attachment of the teeth, the base of which may be either anchylosed to the summit of an alveolar ridge, or to the bottom of an alveolar groove, and supported by its lateral wall. These modifications are indicated respectively by the terms "Acrodont" and "Pleurodont." A third mode of fixation is presented by some extinct Saurians, which, in other parts of their organisation, adhere to the squamate or Lacertine division of the order, the teeth being implanted in sockets, either loosely or confluent with the bony walls of the cavity; these I have termed the "Thecodont"* Lacertians: the most ancient of all Saurians belong to this group; viz. the Thuringian Monitor, or *Protorosaurus*, and the *Palæosaurus* of the dolomitic conglomerates near Bristol. The compressed Varanian form of tooth, with trenchant and finely dentated margins, which characterised the ancient Palœosaur and Chadeiodon, is continued in the comparatively more recent and gigantic species of terrestrial lizard, of which the remains were discovered by Dr. Buckland in the oolite of Stonesfield, by whom the peculiarities of the jaws and teeth have been accurately and graphically described in the following words:—

"From these remains we learn that the animal was a reptile, closely allied to some of our modern lizards; and viewing the teeth as instruments for providing food to a carnivorous creature of enormous magnitude, they appear to have been admirably adapted to the destructive office for which they have been designed. Their form and mechanism will be best explained by reference to the figures.

"The outer margin of the jaw rises nearly an inch above its inner margin, forming a continuous lateral parapet to support the teeth on the exterior side, where the greatest support was necessary, whilst the inner margin throws up a series of triangular plates of bone forming a zigzag buttress along the interior of the alveoli. From the centre of each triangular plate, a bony partition crosses to the outer parapet, thus completing the successive alveoli. The new teeth are seen in the angle between each triangular plate, rising in reserve to supply the loss of older teeth, as often as progressive growth, or accidental fracture, may render such renewal necessary, and thus affording an exuberant provision for a rapid succession and restoration of these most essential implements. They were formed in distinct cavities, by the side of the old teeth, towards the interior surface of the jaw, and probably expelled them by the usual process of pressure and absorption, insinuating themselves into the cavities thus left vacant. This contrivance

* Buckland's Bridgewater Treatise, vol. i. p. 249.

* Odontography, part ii. p. 266.

for the renewal of teeth is strictly analogous to that which takes place in the dentition of many species of existing lizards.

"In the structure of these teeth we find a combination of mechanical contrivances analogous to those which are adopted in the construction of the knife, the sabre, and the saw. When first protruded above the gum, the apex of each tooth presented a double cutting edge of serrated enamel. In this stage, its position and line of action were nearly vertical, and its form, like that of the two-edged point of a sabre, cutting equally on each side. As the tooth advanced in growth it became curved backwards in the form of a pruning-knife, and the edge of serrated enamel was continued downwards to the base of the inner and cutting side of the tooth, whilst on the outer side a similar edge descended but a short distance from the point, and the convex portion of the tooth became blunt and thick, as the back of a knife is made thick for the purpose of producing strength. The strength of the tooth was further increased by the expansion of its side. Had the serrature continued along the whole of the blunt and convex portion of the tooth, it would in this position have possessed no useful cutting power; it ceased precisely at the point beyond which it could no longer be effective. In a tooth thus formed for cutting along its concave edge, each movement of the jaw combined the power of the knife and saw; whilst the apex, in making the first incision, acted like the two-edged point of a sabre. The backward curvature of the full-grown teeth enabled them to retain, like barbs, the prey which they had penetrated. In these adaptations we see contrivances which human ingenuity has also adopted in the preparation of various instruments of art." *

The teeth of the *Megalosaur* consist of a central body of dentine, with an investment of enamel upon the crown, and of cement over all, but thickest upon the fang. The marginal serrations are formed almost entirely by the enamel, and when slightly magnified are seen to be rounded, and separated by slight basal grooves; the smooth and polished enamel upon the sides of the crown presents a finely wrinkled appearance; the remains of the pulp are converted into a coarse bone in the completely formed tooth.

Enaliosaurs. — The teeth of the Ichthyosauri have a simple, more or less acutely conical form, with a long and, usually, expanded or ventricose base, or implanted fang. They are confined to the intermaxillary, maxillary, and premandibular bones, in which they are arranged in a pretty close and uninterrupted series, and are of nearly equal size. They consist of a body of unvascular dentine, invested at the base by a thick layer of cement, and at the crown by a layer of enamel, which is itself covered by a very thin coat of cement; the pulp-cavity is more or less occupied in fully-formed teeth by a coarse bone. The external surface of the tooth is marked by the longitudinal impressions and ridges, but the teeth vary both as to outward sculpturing and general form in the different species.*

The chief peculiarity of the dental system of the Ichthyosaur is the mode of the implantation of the teeth; instead of being anchylosed to the bottom and side of a continuous shallow groove, as in most Lacertians, or implanted in distinct sockets, as in the Thecodon, Megalosaur, or Pterodactyle, they are lodged loosely in a long and deep continuous furrow, and retained by slight ridges between the teeth, along the sides and bottom of the furrow, and by the gum and organised membranes continued into the groove and upon the base of the teeth.

The germs of the new teeth are developed at the inner side of the base of the old ones.

Crocodilia. — The best and most readily recognisable characters by which the existing Crocodilians are grouped in appropriate genera, are derived from modifications of the dental system.

In the Caimans (genus *Alligator*) the teeth vary in number from $\frac{18-18}{18-18}$ to $\frac{22-22}{22-22}$: the fourth tooth of the lower jaw, or canine, is *received into a cavity* of the palatal surface of the upper jaw, where it is concealed when the mouth is shut. In old individuals the upper jaw is perforated by these large inferior canines, and the fossæ are converted into foramina.

In the Crocodiles (genus *Crocodilus*) the first tooth in the lower jaw perforates the palatal process of the premaxillary bone when the mouth is closed; the fourth tooth in the lower jaw is *received into a notch* excavated in the side of the alveolar border of the upper jaw, and is visible externally when the mouth is closed.

In the two preceding genera the alveolar borders of the jaw have an uneven or wavy contour, and the teeth are of an unequal size.

In the Gavials (genus *Gavialis*) the teeth are nearly equal in size and similar in form in both jaws, and the first as well as the fourth tooth in the lower jaw, passes into a groove in the margin of the upper jaw when the mouth is closed.

In the alligators and crocodiles the teeth are more unequal in size, and less regular in arrangement, and more diversified in form than in the Gavials: witness the strong thick conical laniary teeth as contrasted with the blunt mammillate summits of the posterior teeth in the alligator (*fig.* 573.). The teeth of the Gavial are subequal, most of them present the form of crown, shown in *fig.* 572., long, slender, pointed, subcompressed from before backwards, with a trenchant edge on the right and left sides, between which a few faint longitudinal ridges traverse the basal part of the enamelled crown.

* Bridgewater Treatise, vol. i. p. 237.

* Odontography, pl. 73.

Fig. 572.

Teeth in different stages of formation from one alveolus of the Gavial: a is the base partly absorbed by the pressure of *b*, the successional tooth; below which is figured *c*, the germ of the next tooth to follow.

Amongst the remains of Crocodilians which are scattered through the Tilgate strata, the most common ones are detached teeth, from the difference observable in the form of which, Dr. Mantell has observed, that " they appear referable to two kinds, the one belonging to that division of crocodiles with long slender muzzles, named *Gavial*, the other to a species of *Crocodile*, properly so-called, and resembling a fossil species found at Caen."*

Dr. Mantell has obligingly communicated to me figures of well-preserved specimens of both the forms of teeth alluded to, the exactness of which I have recognised by a comparison with the specimens themselves in the British Museum.

The tooth which, from its more slender and acuminated form, approaches nearest to the character of those of the Gavial, presents a marked difference, however, from the teeth of any of the recent species of that sub-genus of Crocodilians, as well as from those of the long and slender-snouted extinct genera, called *Teleosaurus*, *Steneosaurus*, &c. I have described it†, therefore, as indicative of a distinct species, under the name of *Crocodilus cultridens*. The crown is laterally compressed, subincurved, with two opposite trenchant edges, one forming the concave, the other the convex, outline of the tooth. In the Gavial, the direction of the flattening of the crown and the situation of the trenchant edges are the reverse, the compression being from before backwards, and the edges being lateral.‡

The tooth of the *Crocodilus cultridens* thus resembles in form that of the Megalosaur, and perhaps still more those of the Argenton crocodile; but I have not observed any specimens of the Wealden teeth in which the edges of the crown were serrated, as in both the reptiles just cited. The teeth of the *Crocodilus cultridens* also present a character which does not exist in the teeth of the Megalosaur, and is not attributed by Cuvier to those of the *Crocodile d'Argenton*. The sides of the crown are traversed by a few longitudinal parallel ridges, with regular intervals of about one line, in a crown of a tooth one inch and a half in length: these ridges subside before they reach the apex of the tooth, and more rapidly at the convex than at the concave side of the crown.

Hitherto these teeth have not been found so associated with any part of the skeleton of the same species as to yield further characters of the present extinct Crocodilian; but from the above-mentioned well-marked differences between these teeth and those of all the existing species, it is most probable that the extinct crocodile formed the type of a distinct sub-genus, for which the term *Suchosaurus* has been proposed.

The second form of tooth having the generic characters of those of the crocodile, which has been discovered in the Wealden and approximate strata, is as remarkable for its thick, rounded, and obtuse crown as the teeth of the preceding species are for their slender, compressed, acute, and trenchant character. It consequently approaches more nearly to the teeth which characterise the broad and comparatively short-snouted crocodiles; but it differs from these in one of the same characters by which the tooth of the *Suchosaurus cultridens* differs from those of the Gavials, viz., in the longitudinal ridges which traverse the exterior of the crown. These are, however, more numerous, more close-set, and more neatly defined than in the *Suchosaurus cultridens*. Two of the ridges, larger and sharper than the rest, traverse opposite sides of the tooth, from the base to the apex of the crown; they are placed, as in the crocodile and Gavial, at the sides of the crown, midway between the convex and concave lines of the curvature of the tooth. These ridges are confined to the enamel; the cement-covered cylindrical base of the tooth is smooth. The size of the teeth varies from a length of crown of two inches, with a basal diameter of one inch and a half to teeth of one-third of these dimensions. I have proposed to call this extinct crocodile, with biconcave vertebræ, *Goniopholis crassidens*.

Development. — In the black alligator of Guiana the first fourteen teeth of the lower jaw are implanted in distinct sockets, the remaining posterior teeth are lodged close together in a continuous groove, in which the divisions for sockets are faintly indicated by vertical ridges, as in the jaws of the Ichthyo-

* Wonders of Geology, 1839, vol. i. p. 386.

† Odontography, pl. lxii. A, *figs.* 9, 10.

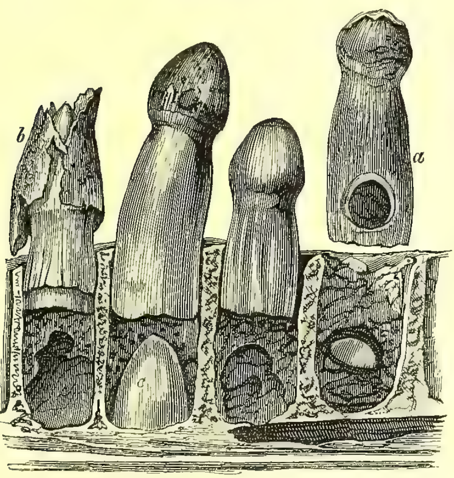
‡ The tooth attributed by M. Deslongchamps to the *Poikilopleuron*, agrees in form with those of the Gavial, and differs in the characters cited in the text from those of the *Crocodilus cultridens*.

saurs. A thin compact floor of bone separates this groove, and the sockets anterior to it, from the large cavity of the ramus of the jaw; it is pierced by bloodvessels for the supply of the pulps of the growing teeth and the vascular dentiparous membrane which lines the alveolar cavities.

The tooth-germ is developed from the membrane covering the angle between the floor and the inner wall of the socket. It becomes in this situation completely enveloped by its capsule, and an enamel-organ is formed at the inner surface of the capsule before the young tooth penetrates the interior of the pulp-cavity of its predecessor.

The matrix of the young growing tooth affects, by its pressure, the inner wall of the socket, as shown in *fig*. 573, and forms for

Fig. 573.



Section of lower jaw, with four alveoli and teeth, of the black Alligator.

itself a shallow recess: at the same time it attacks the side of the base of the contained tooth; then, gaining a more extensive attachment by its basis and increased size, it penetrates the large pulp-cavity of the previously formed tooth either by a circular or semicircular perforation. The size of the calcified part of the tooth-matrix which has produced the corresponding absorption of the previously formed tooth on the one side, and of the alveolar process on the other, is represented in the second exposed alveolus of *fig*. 573., the tooth *a* having been displaced and turned round to show the effects of the stimulus of the pressure. The size of the perforation in the tooth, and of the depression in the jaw, proves them to have been, in great part, caused by the soft matrix, which must have produced its effect by exciting vital action of the absorbents, and not by mere mechanical force. The resistance of the wall of the pulp-cavity having been thus overcome, the growing tooth and its matrix recede from the temporary alveolar depression, and sink into the substance of the pulp contained in the cavity of the fully-formed tooth. As the new tooth grows, the pulp of the old one is removed; the old tooth itself is next attacked, and the crown being undermined by the absorption of the inner surface of its base, may be broken off by a slight external force, when the point of the new tooth is exposed, as in the *fig*. 573. *b*.

The new tooth disembarrasses itself of the cylindrical base of its predecessor, with which it is sheathed, by maintaining the excitement of the absorbent process so long as the cement of the old fang retains any vital connection with the periosteum of the socket; but the frail remains of the old cylinder, thus reduced, are sometimes lifted off the socket upon the crown of the new tooth, as in *fig*. 573. *b*, when they are speedily removed by the action of the jaws. This is, however, the only part of the process which is immediately produced by mechanical force: an attentive observation of the more important previous stages of growth, teaches that the pressure of the growing tooth operates upon the one to be displaced only through the medium of the vital absorbent action which it has excited.

Most of the stages in the development and succession of the teeth of the crocodiles are described by Cuvier with his wonted clearness and accuracy; but the mechanical explanation of the expulsion of the old tooth, which Cuvier adopts from M. Tenon, is opposed by the disproportionate smallness of the hard part of the new tooth to the vacuity in the old one, and by the fact that the matter impressing — viz. the uncalcified part of the walls of the tooth-matrix — is less dense than the part impressed.

No sooner has the young tooth penetrated the interior of the old one, than another germ begins to be developed from the angle between the base of the young tooth and the inner alveolar process, or in the same relative position as that in which its immediate predecessor began to rise, and the processes of succession and displacement are carried on, uninterruptedly, throughout the long life of these cold-blooded carnivorous reptiles.

From the period of exclusion from the egg, the teeth of the crocodile succeed each other in the vertical direction; none are added from behind forwards, like the true molars in Mammalia. It follows, therefore, that the number of the teeth of the crocodile is as great when it first sees the light as when it has acquired its full size; and, owing to the rapidity of the succession, the cavity at the base of the fully-formed tooth is never consolidated.

The fossil jaws of the extinct Crocodilians demonstrate that the same law regulated the succession of the teeth, at the ancient epochs when those highly organised reptiles prevailed in greatest numbers, and under the most varied generic and specific modifications, as at the present period, when they are reduced to a single family, composed of so few and slightly varied species as to have constituted in the system of Linnæus a small fraction of his genus Lacerta.

Dental System of Mammals.

The class Mammalia, like that of *Reptilia* and *Pisces*, includes a few genera and species that are devoid of teeth: the true ant-eaters (*Myrmecophaga*), the scaly ant-eaters or Pangolins (*Manis*), and the spiny monotrematous ant-eater (*Echidna*), are examples of strictly edentulous Mammals. The *Ornithorhynchus* has horny teeth, and the whales (*Balæna* and *Balænoptera*) have transitory embryonic calcified teeth*, succeeded by whalebone substitutes† in the upper jaw. Horny processes analogous to, perhaps homologous with, the lingual and palatal teeth in fishes, are present in the *Echidna*.

The female Narwhal seems to be edentulous, but has the germs of two tusks in the substance of the upper jaw-bones; one of these becomes developed into a large and conspicuous weapon in the male Narwhal, and, accordingly, suggested to Linnæus the name, for its genus, of *Monodon*, meaning single tooth: but the tusk is never median, like the truly single tooth on the palate of the Myxine; and occasionally both tusks are developed in the Narwhal. In another Cetacean, the great Bottle-nose, or *Hyperoodon*, the teeth are reduced in the adult to two in number, whence the specific name *H. bidens*, but they are confined to the lower jaw. The sharp-nosed dolphin (*Ziphius*) has also but two teeth, one in each ramus of the lower jaw; and this is, perhaps, a sexual character. The *Delphinus griseus* has five teeth on each side of the lower jaw; but they soon become reduced to two. Amongst the marsupial animals, the genus *Tarsipes* is remarkable for the paucity as well as minuteness of its teeth.

The elephant has never more than one entire molar, or parts of two, in use on each side of the upper and lower jaws; to which are added two tusks, more or less developed, in the upper jaw.

Some Rodents, as the Australian Water-rats (*Hydromys*), have two grinders on each side of both jaws; which, added to the four cutting teeth in front, make twelve in all: the common number of teeth in this order is twenty; but the hares and rabbits have twenty-eight teeth. The sloth has eighteen teeth. The number of teeth, thirty-two, which characterises man, the apes of the old world, and the true ruminants, is the average one of the class Mammalia; but the typical number is forty-four.

The examples of excessive number of teeth are presented, in the order *Bruta*, by the Priodont Armadillo, which has ninety-eight teeth; and, in the cetaceous order, by the Cachalot, which has upwards of sixty teeth, though most of them are confined to the lower jaw; by the common porpoise, which has between eighty and ninety teeth; by the Gangetic dolphin, which has one hundred and twenty teeth; and by the true dolphins (*Delphinus*), which have from one hundred to one hundred and ninety teeth, yielding the maximum number in the class Mammalia.

Form.—Where the teeth are in excessive number, as in the species above cited, they are small, equal, or subequal, and of a simple conical form; pointed, and slightly recurved in the common dolphin; with a broad and flattened base in the gangetic dolphin (*Inia*); with the crown compressed, and broadest in the porpoise; compressed but truncate, and equal with the fang, in the Priodon. The compressed triangular teeth become coarsely notched or dentated, at the hinder part of the series, in the great extinct cetaceous *Zeuglodon*. The simple dentition of the smaller Armadillos, of the Orycterope, and of the three-toed Sloth, presents a difference in the size, but little variety in the shape of the teeth, which are subcylindrical, with broad triturating surfaces; in the two-toed Sloth, the two anterior teeth of the upper jaw are longer and larger than the rest, and adapted for piercing and tearing.

In almost all the other Mammalia, particular teeth have special forms for special uses: thus, the front teeth, from being commonly adapted to effect the first coarse division of the food, have been called cutters or *incisors*; and the back teeth, which complete its comminution, grinders or *molars*; large conical teeth, situated behind the incisors, and adapted by being nearer the insertion of the biting muscles, to act with greater force, are called holders, tearers, laniaries, or more commonly *canine* teeth, from being well developed in the dog and other Carnivora, although they are given, likewise, to many vegetable feeders for defence or combat: *e.g.* Musk-deer (*fig.* 580, VII.). Molar teeth, which are adapted for mastication, have either tuberculate, or ridged, or flat, summits; and usually are either surrounded by a fence of enamel, or are traversed by enamel plates arranged in various patterns. Certain molars in the Dugong, the Mylodon, and the Zeuglodon, are so deeply indented laterally by opposite longitudinal grooves, as to appear, when abraded, to be composed of two cylindrical teeth cemented together, and the transverse section of the crown is bilobed. The teeth of the *Glyptodon* were fluted by two analogous grooves on each side. The large molars of the Capybara and Elephant have the crown cleft into a numerous series of compressed transverse plates, cemented together side by side.

The teeth of the Mammalia have usually so much more definite and complex a form than those of fishes and reptiles, that three parts are recognised in them: viz. the "fang," the "neck," and the "crown." The fang or root (*radix*) is the inserted part; the crown (*corona*) the exposed part; and the construction which divides these is called the neck (*cervix*). The term "fang" is properly given only to the implanted part of a tooth of re-

* Odontography, pl. 87 *a*, *figs.* 1—6.

† Ib. pl. 76, *figs.* 4. 6; art. Cetacea, Vol. I. p. 572, *fig.* 259 *b*.

stricted growth, which fang gradually tapers to its extremity; those teeth which grow uninterruptedly have not their exposed part separated by a neck from their implanted part, and this generally maintains to its extremity the same shape and size as the exposed crown.

It is peculiar to the class Mammalia to have teeth implanted in sockets by two or more fangs; but this can only happen to teeth of limited growth, and generally characterises the molars and premolars; perpetually growing teeth require the base to be kept simple and widely excavated for the persistent pulp. In no mammiferous animal does anchylosis of the tooth with the jaw constitute a normal mode of attachment. Each tooth has its particular socket, to which it firmly adheres by the close co-adaptation of their opposed surfaces, and by the firm adhesion of the alveolar periosteum to the organised cement which invests the fang or fangs of the tooth; but in some of the Cetacea, at the posterior part of the dental series, the sockets are wide and shallow, and the teeth adhere more strongly to the gum than to the periosteum; in the Cachalot I have seen all the teeth brought away with the ligamentous gum, when it has been stript from the sockets of the lower jaw.

Teeth are fixed as a general rule in all Vertebrata, and the only known exceptions are those presented by certain species of fishes, *e.g.* the Sharks, Lophioids, Goniodonts. In the higher Vertebrata the movements of the teeth depend on those of the jaw-bones to which they are affixed, but appear to be independent in the ratio of the size of the tooth to the bone to which it is attached. Thus the extent of rotatory movement to which the large perforated poison fangs of the rattle-snake are subject depends upon the rotation of the small maxillary bone. So likewise the seemingly individual movements of divarication and approximation observable in the large lower incisors of the *Bathyergus* and *Macropus* *, are due entirely to the yielding nature of the symphysis uniting the two rami of the lower jaw in which those incisors are deeply and firmly implanted. It is no more a property of the teeth themselves than is that alternate removal of the lower teeth from, and bringing of them in contact with, the upper teeth of the mouth, which one sees or feels in the act of mastication.

True teeth implanted in sockets are confined, in the Mammalian class, to the maxillary, premaxillary, and mandibular, or lower maxillary bones, and form a single row in each. They may project only from the premaxillary bones, as in the Narwhal, or only from the lower maxillary bone, as in Ziphius; or be apparent only in the lower maxillary bone, as in the Cachalot; or be limited to the superior and inferior maxillaries, and not present in the premaxillaries, as in the true *Pecora*, and most *Bruta* of Linnæus; in general, teeth are situated in all the bones above mentioned. In Man, where the premaxillaries early coalesce with the maxillary bones, where the jaws are very short and the crowns of the teeth are of equal length, there is no interspace or "diastema" in the dental series of either jaw, and the teeth derive some additional fixity by their close apposition and mutual pressure. No inferior Mammal now presents this character; but its importance, as associated with the peculiar attributes of the human organisation, has been somewhat diminished by the discovery of a like contiguous arrangement of the teeth in the jaws of a few extinct quadrupeds: e. g. *Anoplotherium*, *Nesodon*, and *Dichodon*.*

The teeth of the Mammalia usually consist of hard unvascular dentine, defended at the crown by an investment of enamel, and everywhere surrounded by a coat of cement. The coronal cement is of extreme tenuity in Man, Quadrumana, and terrestrial Carnivora; it is thicker in the Herbivora, especially in the complex grinders of the Elephant; and is thickest in the teeth of the Sloths, Megatherioids, Dugong, Walrus, and Cachalot. Vertical folds of enamel and cement penetrate the crown of the tooth in the Ruminants, and in most Rodents and Pachyderms, characterising by their various forms the genera of the last two orders; but these folds never converge from equidistant points of the circumference of the crown towards its centre. The teeth of the quadrupeds of the order *Bruta* (*Edentata*, Cuv.) have no true enamel; this is absent likewise in the molars of the Dugong and the Cachalot.† The tusks of the Narwhal, Walrus, Dinotherium, Mastodon, and Elephant consist of modified dentine, which, in the last two great proboscidian animals, is properly called "ivory," ‡ and is covered by cement.

In the subjoined magnified view of a section of the molar of a Megatherium, *t* is the hard dentine, *v* the vaso-dentine, and *c* the cement (*fig.* 574).

The teeth in the Mammalia, as in the foregoing classes, are formed by superaddition of the hardening salts to pre-existing moulds of animal pulp or membrane, organised so as to insure the arrangement of the earthy particles according to that pattern which characterises each constituent texture of the tooth.

The complexity of the primordial basis, or matrix, corresponds, therefore, with that of the fully-formed tooth, and is least remarkable in those conical teeth which consist only

* See Mason Good's Book of Nature, vol. i. p. 285. 1826.

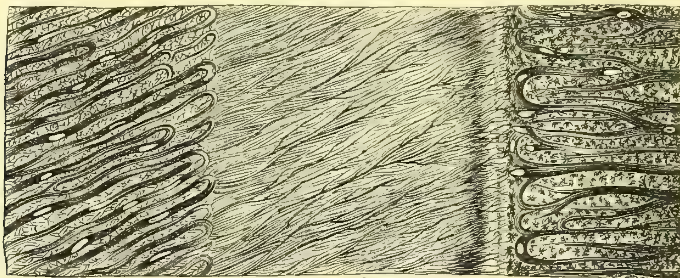
* Quarterly Journal of the Geological Society, Feb. 1848, p. 36, pl. iv.

† M. Fr. Cuvier divides the teeth of Mammalia, according to their composition, into four classes: the first consists of ivory (dentine), enamel, and cement; the second of ivory and enamel; the third of ivory and cement; the fourth of ivory only. (Dents des Mammifères, p. xxi.) I have met with no Mammalian teeth in which cement is absent, and believe that the second and fourth of the above-cited classes of teeth have no existence in nature.

‡ "Hoc solum est ebur." *Plinius, Hist. Nat.* lib. xi. c. 37.

of dentine and cement. The primary pulp, which first appears as a papilla rising from the

Fig. 574.



ree surface of the alveolar gum, is the part of the matrix which by its calcification constitutes the dentine; it sinks into a cell and becomes surrounded by a closed capsule in every mammiferous species, at an early stage of the formation of the tooth; and, as the cement is the result of the ossification of the capsule, every tooth must be covered by a layer of that substance. In those teeth which possess enamel, the mould or pulp of that constituent is developed from the capsule covering the coronal part of the dentinal pulp. In the simple teeth the secondary or enamel pulp covers the crown like a cap; in the complex teeth it sends processes into depressions of the crown, which vary in depth, breadth, direction, and number in the numerous groups of the herbivorous and omnivorous quadrupeds. The dentinal pulp, thus penetrated, offers corresponding complications of form; and as the capsule follows the enamel pulp in all its folds and processes, the external cavities or interspaces of the dentine become occupied by enamel and cement; the cement, like the capsule which formed it, being the outermost substance, and the enamel being interposed between it and the dentine. The dental matrix presents the most extensive interdigitation of the dentinal and enamel pulps in the Capybara and Elephant. The processes of formation and calcification of the several constituents of Mammalian teeth will be found described in the Introduction to my "Odontography"* and in the article Tooth.

The matrix of the Mammalian tooth sinks into a furrow and soon becomes inclosed in a cell in the substance of the jaw-bone, from which the crown of the growing tooth extricates itself by exciting the absorbent process, whilst the cell is deepened by the same process and by the growth of the jaw into an alveolus for the root of tne tooth. Where the formative parts of the tootn are reproduced indefinitely to repair by their progressive calcification the waste to which the working surface of the crown of the tooth has been subject, the alveolus is of unusual depth, and of the same form and diameter throughout, except in the immature animal, when it widens to its bottom or base. In teeth of limited growth, the dentinal pulp is reproduced in progressively decreasing quantity after the completion of the exterior wall of the crown, and forms by its calcification one or more roots or fangs, which taper more or less rapidly to their free extremity. The alveolus is closely moulded upon the implanted part of the tooth; and it is worthy of special remark that the complicated form of socket which results from the development of two or more fangs is peculiar to animals of the class Mammalia.*

In the formation of a single fang the activity of the reproductive process becomes enfeebled at the circumference, and is progressively contracted within narrower limits in relation to a single centre, until it ceases at the completion of the apex of the fang; which, though for a long time perforated for the admission of the vessels and nerves to the interior of the tooth, is, in many cases, finally closed by the ossification of the remaining part of the capsule.

When a tooth is destined to be implanted by two or more fangs, the reproduction of the pulp is restricted to two or more parts of the base of the coronal portion of the pulp, around the centre of which parts the sphere of its reproductive activity is progressively contracted. The intervening parts of the base of the coronal pulp adhere to the capsule, which is simultaneously calcified with them, covering those parts of the base of the crown of the tooth with a layer of cement. The ossification of the surrounding jaw being governed by the changes in the soft, but highly organised, dental matrix, fills up the

* P. xli.

* On the strength of this generalisation, I have established the Mammalian nature of the huge extinct animal called *Basilosaurus* by Dr. Harlan, and have advocated the claims of the diminutive *Amphitherium* and *Phascolotherium* of the oolitic slate of Stonesfield to be admitted into the same high class, against the objections raised by M. de Blainville. See "Comptes Rendus de l'Acad. des Sciences," Oct. 22, 1838. The bifid base of the teeth of certain sharks not being implanted in a socket, forms no true exception to the rule enunciated in the text. See Geological Transactions, 2d series, vol. vi. p. 66.

spaces unoccupied by the contracted and divided pulp, and affords, by its periosteum, a surface for the adhesion of the cement or ossified capsule covering the completed part of the tooth.

The matrix of certain teeth does not give rise during any period of their formation to the germ of a second tooth, destined to succeed the first; this, therefore, when completed and worn down, is not replaced: all the true Cetacea are limited to this simple provision of teeth. In the Armadillos, Megatherioids, and Sloths, the want of germinative power, as it may be called, in the matrix is compensated by the persistence of the matrix, and by the uninterrupted growth of the teeth.

In most other Mammalia, the matrix of the first developed tooth gives origin to the germ of a second tooth, which sometimes displaces, sometimes takes its place by the side of, its predecessor and parent. All those teeth which are displaced by their progeny are called temporary, deciduous, or milk teeth; the mode and direction in which they are displaced and succeeded, — viz., from above downwards in the upper, from below upwards in the lower, jaw; in both jaws vertically—are the same as in the Crocodile; but the process is never repeated more than once in any mammiferous animal. A considerable proportion of the dental series is thus changed; the second, or permanent teeth, having a size and form as suitable to the jaws of the adult, as the displaced temporary teeth were adapted to those of the young, animal. The permanent teeth, which assume places not previously occupied by deciduous ones, are always the most posterior in their position, and generally the most complex in their form. The successors of the deciduous incisors and canines differ from them chiefly in size; the successors of the deciduous molars may differ likewise in shape, in which case they have always less complex crowns than their predecessors.*

The "bicuspids," in Human Anatomy, and the corresponding teeth, called "premolars," in the lower Mammals, illustrate this law.

The first true molar owes the germ of its matrix to a vegetation or bud, separated by the fissiparous process from the matrix of the last deciduous tooth; but the backward elongation of the jaw affords space for its development by the side of its progenitor, during which process it may in like manner give origin to a second, and this to a third, molar, succeeding each other from before backwards or horizontally.

In this successive germ-production, we find repeated the multiparous property of the dental matrix of the crocodile; but the concomitant growth of the jaw allows the second, third, and sometimes fourth generation of true molars to co-exist, and come into place side by side. In the Unguiculate, and most of the Ungulate, species of the placental division of the Mammalian class, the fissiparous reproduction of horizontally succeeding teeth stops at the third generation; in other words, they have not more than three true molars on each side of the upper and lower jaws. In the Marsupial series, the same process extends to a fourth generation of true or horizontally succeeding molars*; and in most of the species, the four true molars are in use and place at the same time; but in certain Kangaroos, the anterior ones are shed before the posterior ones are developed. This successive decadence is still more characteristic of the grinding teeth of the Elephant, which are finally reduced to a single molar tooth on each side of both jaws.

Thus the class Mammalia, in regard to the times of formation and the succession of the teeth, may be divided into two groups: — the "*Monophyodonts*,"† or those that generate a single set of teeth; and the "*Diphyodonts*,"‡ or those that generate two sets of teeth.

The Monophyodonts include the orders *Monotremata*, *Bruta* (*Edentata*, Cuv.), and *Cetacea* (*Cetacea vera*, Cuv.): all the rest of the order are Diphyodonts. In these, the first set of teeth are called the milk or deciduous teeth: the second set, the adult or permanent teeth; although the teeth of this set are for the most part, like those of the first set, of limited growth, contracting to a root or roots, and being shed in greater or less proportion during the life-time of the species; which life-time, in wild Carnivora and Herbivora, is dependent on, and would seem, indeed, to be determined by, the duration of the adult teeth.

The particulars of the Monophyodont dentition will be found under the Articles MONOTREMATA, Vol. III. p. 387.; CETACEA, Vol. I. pp. 563. 571. 573.; (see my Odontography, p. 345. pls. 87—91.); and EDENTATA, Vol. II. p. 53.; (see also Odontography, p. 317. pls. 76—86.) Examples of some of the striking modifications of dental structure presented by recent or extinct animals of the order *Bruta*, are given in *figs.* 548. and 574. of the present article. It will be observed that I have qualified the generalisation as regards the Monophyodont character of the *Cetacea*, by citing only that part of Cuvier's order which he termed "true or carnivorous Cetacea." The animals of the order *Sirenia*

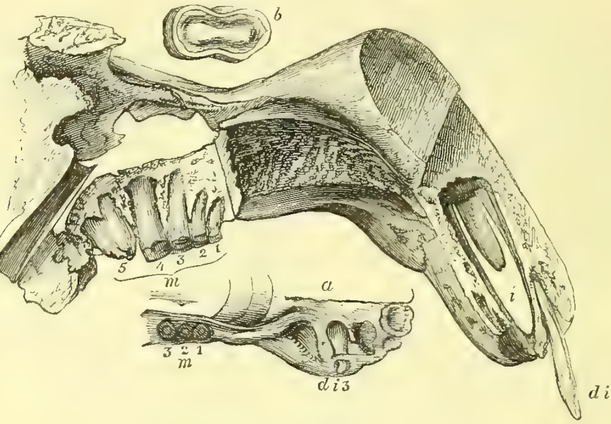
* "C'est une règle générale, que les molaires de remplacement ont une couronne moins compliquée que celles auxquelles elles succèdent; mais cette couronne compliquée se trouve reportée sur les molaires permanentes qui viennent plus en arrière." This generalisation was established by Cuvier, in his Leçons d'Anat. Comp., ed. 1805. vol. iii. p. 135.

* This characteristic extension of the reproductive power of the matrices of the true molars in the Marsupials, is an approximation to the peculiar activity and persistence of the same power in the vertically succeeding teeth of the cold-blooded Ovipara, and is associated with many other instances of the same affinity in more important parts of the organization of the implacental Mammals.

† μόνος, once; φύω, I generate; ὀδους, tooth.

‡ δίς, twice; φύω and ὀδους.

Fig. 575.



Dentition of the Dugong (Halicore indicus).

(herbivorous Cetacea of Cuvier) differ in many organic particulars from the *Cetacea* proper*, and in none, perhaps, more strikingly than in having both deciduous and permanent teeth; this succession takes place, at least, with regard to the upper incisors of the *Dugong*, *fig.* 575.

These teeth project from the gum in the male sex; but neither upper nor lower incisors are visible in the female.† The superior incisors are but two in number, in both sexes; in the male, they are moderately long, subtriedral, slightly and equally curved, of the same diameter from the base, and deeply excavated to near the apex, which is obliquely bevelled off to a sharp edge, like the scalpriform teeth of the *Rodentia.* The form and extent of the persistent pulp-cavity of this tooth are shown in the figure of its longitudinal section, in my "Odontography," pl. 93. *fig.* 4.; it becomes longer and more pointed than in the permanent incisor of the younger male (*fig.* 575, *i*). When fully developed, only the extremity of this tusk projects from the jaw, at least seven-eighths of its extent being lodged in the socket, the parietes of which are entire; and the exterior of the great premaxillary bones presents an unbroken surface. In the female Dugong, the growth of the permanent incisive tusks of the upper jaw is arrested before they cut the gum, and they remain through life concealed in the premaxillaries; the tusk is solid, is about an inch shorter and less bent than that of the male; it is also irregularly cylindrical, longitudinally indented, and it gradually diminishes to an obtuse rugged point; the base is suddenly expanded, bent obliquely outwards, and presents a shallow excavation. These were conjectured by Home to be the "milk-tusks;" they are, however, characteristic of sex, not of age; and the existence of deciduous tusks at any period in the Dugong has been called in question.* I have, however, discovered in specimens of the Malayan Dugong which I have dissected at the Zoological Society, the true deciduous incisors of the upper jaw (*fig.* 575, *d i*) coexisting with the permanent ones (*i*). They are much smaller than the permanent tusks of the female, and are loosely inserted by one extremity in conical sockets immediately anterior to those of the permanent tusks, adhering by their opposite ends to the thick tegumentary gum, which presented no outward indication of their presence.

When this gum was stripped off the bone, the deciduous tusks came away with it; and this may account for their usual absence in dried crania of immature Dugongs, in which, nevertheless, their alveoli are generally sufficiently conspicuous. True permanent incisors are not developed in the lower jaw of the Dugong; those which are occasionally found there are abortive remnants of the first or deciduous series, which are not destined at any time to rise above the gum (*fig.* 575, *d i* 3.).

The molar teeth of the Dugong resemble those of the order *Bruta* in the total absence of enamel, and of any constriction defining the crown from the fangs. In the Malayan species, only five molars (*fig.* 575, 1, 2, 3, 4, 5.) are developed on each side of both jaws: in the Australian Dugong six are developed; *i. e.* the *Halicore indicus* is characterised by the molar formula $m. \frac{5-5}{5-5}=20$, whilst the *Halicore australis* has $m. \frac{6-6}{6-6}=24$.† But in both species, the number is progressively reduced, by the shedding of the anterior and smaller molars, to $m. \frac{2-2}{2-2}=8$. The structure of these molar teeth is illustrated in

* Proceedings of the Zoological Society of London, 1838, p. 40.

† Proceedings of the Zool. Society, 1838, p. 41.

* Dr. Knox, Edinburgh Philosophical Transactions, tom. xi. p. 389.

† See my appendix to Juke's "Voyage of the Fly.'

fig. 546. B, their form in *fig.* 546. A; the last molar, when it comes into use, presents a bilobed form of grinding surface, as is shown at *b*, *fig.* 575.

Owing to there being but one set of molars in the Dugong, those teeth cannot be divided into true and false molars, any more than in the Sloths or Armadillos. In the true Diphyodonts, in which each kind of teeth have deciduous predecessors, those grinders which succeed the deciduous ones vertically, and displace them, are called "premolars," or "false molars," and those that come into place behind these, without pushing out vertically any predecessors, are the "molars proper," or "true molars." In this article, as in my "Odontography," the two sorts of grinders are called respectively "premolars" and "molars." In the Marsupial order the normal number of molars is four in each dental series, *i.e.* $m. \frac{4-4}{4-4}$; in the placental Diphyodonts their normal number is three, *i. e.* $m. \frac{3-3}{3-3}$; the normal number of premolars in the Marsupialia is $\frac{3-3}{3-3}$, but in the Placentalia, it is $\frac{4-4}{4-4}$: in both the numerical character of the canines is one, *i. e.* $\frac{1-1}{1-1}$; that of the incisors three, *i. e.* $\frac{3-3}{3-3}$. As regards the latter teeth, however, the number of exceptions in the *Marsupialia* is considerable, and the incisors are sometimes in excess; whilst in the placental Diphyodonts, the incisors never exceed the typical number, but frequently depart from it by suppression or arrest of development.

In fishes and reptiles, certain teeth might be called "incisive," "laniary," or "molar" teeth, in reference to the special adaptation of their form for cutting, tearing, or bruising; but such terms, in the cold-blooded classes, imply nothing more than those modifications of form; they are not significative of constant and well-defined groups of teeth, and could not become the names of definite parts or organs determinable and traceable from one species to another. In the Mammalian orders, with two sets of teeth, these organs acquire fixed individual characters, receive special denominations, and can be determined from species to species. This individualisation of the teeth is eminently significative of the high grade of organisation of the animals manifesting it; especially when we consider the great proportion of mineral substance which enters into the composition of those parts; in the number and nature of which the principle of vegetative repetition, and the power of the general polarising forces, have been most controlled in the Mammalia.

Originally, indeed, the name "incisors," "laniaries" or "canines," and "molars" were given to the teeth, in Man and certain mammals, as in reptiles, in reference merely to the shape and offices so indicated; but they are now used as arbitrary signs, in a more fixed and determinate sense. In some Carnivora, *e.g.*, the front teeth have broad tuberculate summits, adapted for nipping and bruising, while the principal back teeth are shaped for cutting, and work upon each other like the blades of scissors. The front teeth in the elephant project from the upper jaw, in the form, size, and direction of long pointed horns. In short, shape and size are the least constant of dental characters in the Mammalia; and the homologous teeth are determined, like other parts, by their relative position, by their connections, and by their development.

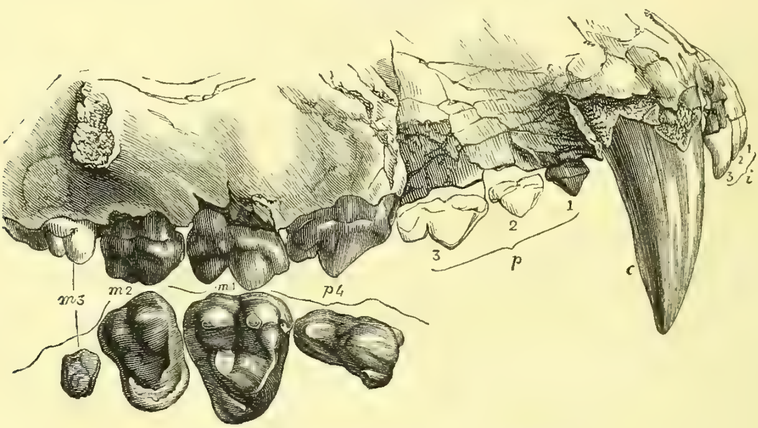
Those teeth which are implanted in the premaxillary bones, and in the corresponding part of the lower jaw, are called "incisors," whatever be their shape or size. The tooth in the maxillary bone, which is situated at, or near to, the suture with the premaxillary, is the "canine," as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth of the first set are the "deciduous molars;" the teeth which displace and succeed them vertically are the "premolars;" the more posterior teeth, which are not displaced by vertical successors, are the "molars" properly so called.

When the premolars and the molars are below their typical number, the absent teeth are missing from the fore-part of the premolar series and from the back part of the molar series. The most constant teeth are the fourth premolar and the first true molar; and, these being known by their order and mode of development, the homologies of the remaining molars and premolars are determined by counting the molars from before backwards, *e. g.* "one," "two," "three;" and the premolars from behind forwards, *e. g.* "four," "three," "two," "one." The incisors are counted from the median line, commonly the foremost part of both upper and lower jaws, outwards and backwards. The first incisor of the right side is the homotype, transversely, of the contiguous incisor of the left side in the same jaw, and, vertically, of its opposing tooth in the opposite jaw; and so with regard to the canines, premolars, and molars; just as the right arm is the homotype of the left arm in its own segment, and also of the right leg of a succeeding segment. It suffices, therefore, to reckon and name the teeth of one side of either jaw in a species with the typical number and kinds of teeth; *e.g.* the first, second, and third incisors,—the first, second, third, and fourth premolars,—the first, second, and third molars; and of one side of both jaws in any case.

The homologous teeth being thus determinable, they may be severally signified by a symbol as well as by a name. The incisors, *e.g.*, by their initial letter *i.*, and individually by an added number, *i.* 1, *i.* 2, and *i.* 3; the canines by the letter *c.*; the premolars by the letter *p.*; and the molars by the letter *m.*; these also being differentiated by added numerals. Thus, the number of these teeth, on each side of both jaws, in any given species, Man *e.g.*, may be expressed by the following brief formula: — $i.\ \frac{2-2}{2-2},\ c.\ \frac{1-1}{1-1},\ p.\ \frac{2-2}{2-2},\ m.\ \frac{3-3}{3-3}=32$; and the homologies of the individual teeth, in relation to the typical formula, may be signified by *i.* 1., *i.* 2.; *c.*; *p.* 3., *p.* 4.; *m.* 1., *m.* 2., *m.* 3.: the suppressed teeth being *i.* 3.*, *p.* 1., and *p.* 2.

Examples of the typical dentition are exceptions in the actual creation; but it was the rule in the forms of Mammalia first introduced into this planet; and that, too, whether the teeth were modified for animal or vegetable food. *Fig.* 576., *e. g.*, shows the dental series

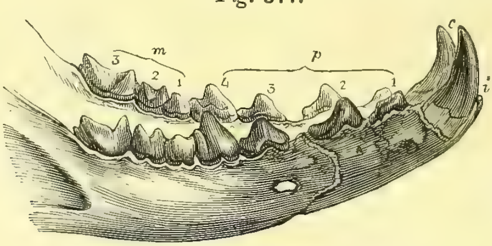
Fig. 576.



Dentition of the Amphicyon major. Upper jaw.

of the upper jaw of the *Amphicyon major*, a mixed-feeding ferine animal, allied to the Bear. *Fig.* 577. shows the dental series of the under jaw of a more strictly carnivorous

Fig. 577.



Dentition of the Hyænodon. Lower jaw.

beast, the *Hyænodon;* the fossil remains of a species of which have been discovered in the oldest tertiary deposits of Hampshire. The symbols denote the homologies of the teeth.

* I have been guided by the analogy of the hare (Odontography, p. 410, pl. 104, *fig.* 5.) in this determination; but a contradictor might indulge his instinct without liability to disproof from actual knowledge.

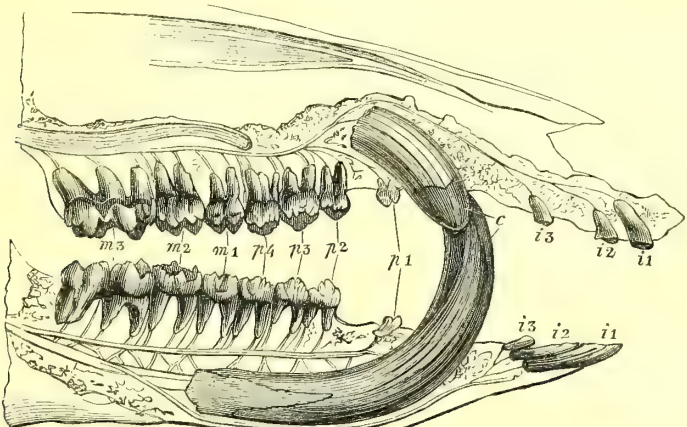
The true molars in the one are tuberculate, indicating its tendency to vegetable diet; in the other, they are carnassial, and betoken a peculiarly destructive and bloodthirsty species.

In the Quarterly Geological Journal, No. 13, 1848, p. 36. pl. iv., I have described and figured the entire dental series of one side of the lower jaw of an extinct hoofed quadruped, the *Dichodon cuspidatus,* from eocene or oldest tertiary strata, also manifesting the normal number and kinds of teeth, but with such equality of height of crown, that no interspace is needed to lodge any of the teeth when the jaws are closed, and the series is as entire and uninterrupted as in the human subject. A great proportion of the upper jaw and teeth has been discovered, and the marks of abrasion on the lower teeth prove the series above to have been as entire and continuous as that below. The *Anoplotherium* (" Odontography," pl. 135. *fig.* 1.), from the gypsum quarries of Montmartre, geologically as ancient as the eocene clays of this island, long ago presented to Cuvier the same peculiar continuous dental series as is shown in the *Dichodon.* In his original Memoir, Cuvier described the canines as a fourth pair of incisors, on account of their small size and their trenchant shape; but he afterwards recognised their true homology with the larger and more laniariform canines of the *Palæotherium* ("Odontography," pl. 135., *fig.* 4.). The *Chæropotamus**, the *Anthracotherium*†, the *Hyopotamus*‡, the *Hyracotherium*§, the *Oplotherium*, the *Merycopotamus*, the *Hippohyus*, and other ancient (eocene and miocene) tertiary mammalian genera presented the forty-four teeth, in number and kind according to that which is here propounded as the typical or normal dentition of the placental Mammalia. Amongst the existing genera, the hog (*Sus*) is one of the few that retain this type. *Fig.* 578. shows the entire permanent series, exposed, in both jaws, and indicated individually by their symbols. *Fig.* 579. illustrates the phenomena of development which distinguish the premolars from the molars. The first premolar, *p.* 1, and the first molar, *m.* 1, are in place and use, together with the three deciduous molars, *d.* 2, *d.* 3, and *d.* 4; the second molar, *m.* 2, has just begun to cut the gum; *p.* 2, *p.* 3, and *p.* 4, together with *m.* 3, are more or less incomplete and concealed in their closed alveoli.

The premolars must displace deciduous molars in order to rise into place; the molars have no such relations; it will be observed, that the last deciduous molar, *d.* 4, has the same relative superiority of size to *d.* 3 and *d.* 2 which *m.* 3 bears to *m.* 2 and *m.* 1; and the crowns of *p.* 3 and *p.* 4 are of a more simple form than those of the milk-teeth which they are destined to succeed.

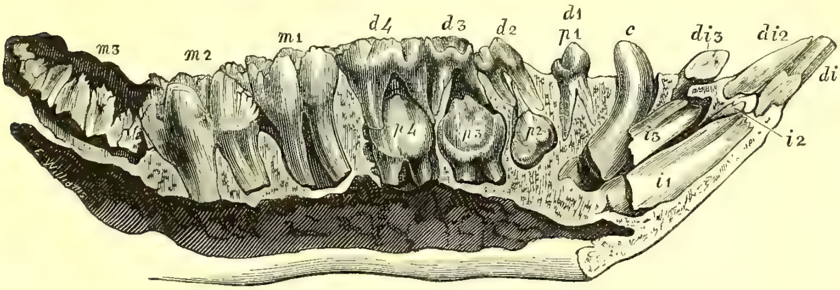
Teeth of each of the kinds above determined, and arbitrarily named "incisors," "canines," "premolars," "molars," have received other special names in regard to certain peculiarities of form or other property; and the ablest comparative anatomists have been led astray in determining their homologies when they have suffered themselves to be guided exclusively by morphological characters. The premolars in the human subject have been called "bicuspids." The last upper premolar and the first lower true molar in the Carnivora are termed, from their peculiar form, "sectorials," or "carnassial teeth," "molaires carnassières" of Cuvier. Teeth

Fig. 578.



Dentition of the Hog (Sus).

Fig. 579.



Deciduous and permanent teeth (Sus). *Lower jaw.*

* History of British Fossil Mammalia, p. 416, *fig.* 164.

† Jobert, Annales des Sciences, t. xvii. p. 139.

‡ Quarterly Journal of the Geological Society, May, 1848, p. 103, pl. viii.

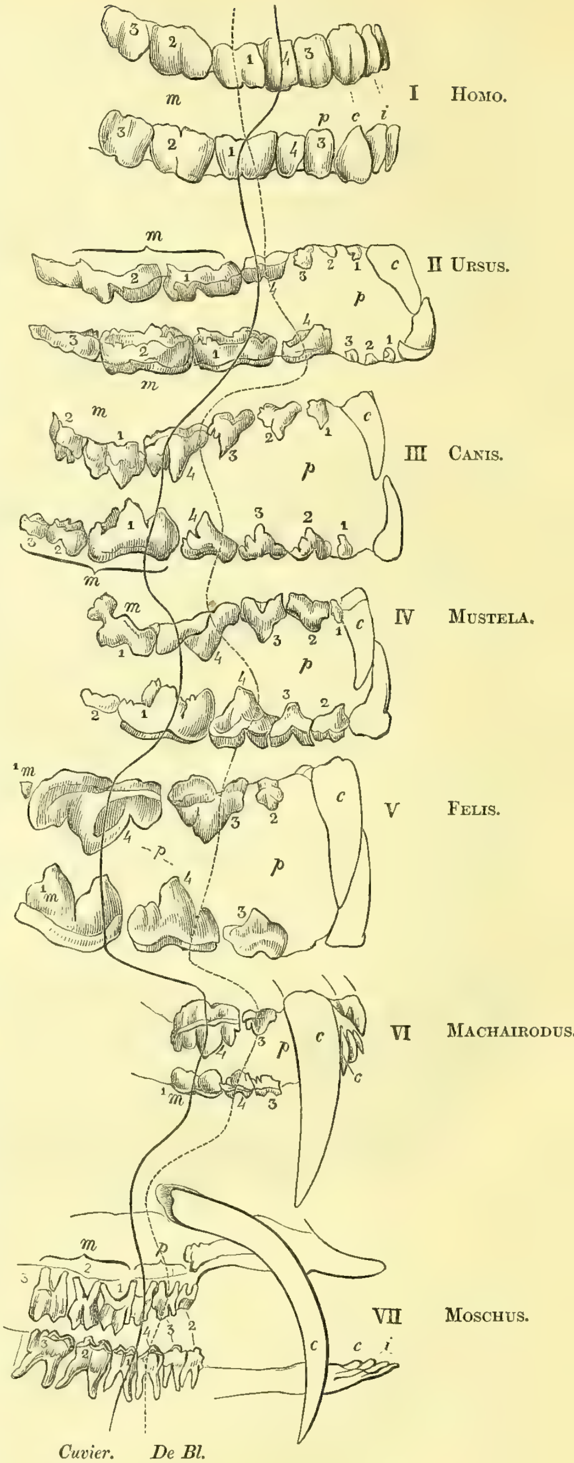
§ Geological Transactions, 2nd series, vol. vi. p. 203.

of an elongated conical form, projecting considerably beyond the rest, and of uninterrupted growth, are called "tusks;" such are the incisors of the Elephant and Dugong, the canines of the Boar and Walrus: the long and large incisors of the Rodents have been termed, from the shape and structure of their cutting edge, scalpriform or chisel-teeth, "*dentes scalprarii.*" The inferior incisors of the flying Lemurs (*Galeopithecus*) have the crown deeply notched like a comb, and are termed "*dentes pectinati.*" The canines of the Baboons are deeply grooved in front, like the poison-fangs, "*dentes canaliculati,*" of some serpents. The compressed conical crowns of the molar teeth of the small clawed seals (*Stenorhynchus*) are divided either like a trident, into three sharp points, or like a saw, into four or five points; the molars of the great extinct *Zeuglodon* had a similar form; such teeth have been called *dentes serrati.* But the philosophical course of the knowledge of nature tends to explode needless terms of art, invented for unimportant varieties, and to establish and fix the meaning of those terms that are the signs of determinate species of things.

The Cuviers divided the molar series of teeth, according to their form, into three kinds: "false molars," "carnassials," and "tubercular molars;" and, in giving the generic characters of Mammalia, based the dental formulæ on this system: thus the genus *Felis* is characterised as having "fausses molaires $\frac{2-2}{2-2}$, carnassières $\frac{1-1}{1-1}$, tuberculeuses $\frac{1-1}{0-0}$; $=\frac{8}{6}$."*

The uninterrupted line marked "Cuvier" in V. Felis of *fig.* 580., intersects the teeth in each jaw called carnassières; those anterior to them being the teeth called "fausses molaires;" the single tooth behind in the upper jaw is the "tuberculeuse." Most Zoologists, both at home and abroad, have adopted the Cuvierian system of formalising the molar teeth. It seems a very natural one in the case of the Cat

Fig. 580.



Homologies of the teeth in Diphyodont Mammals.

* "Les Dents des Mammifères considérées comme Caractères zoologiques," 8vo. p. 77. In the original the numbers are given f. m. $\frac{4}{4}$; c. $\frac{2}{2}$; t. $\frac{2}{0}$, the teeth of each side being clubbed together; they are distinguished into right and left in the text, to facilitate the comparison with the formulæ used in this Article.

genus; the tooth *p.* 4 above plays upon that, *m.* 1, below, which has a similar remarkable carnassial modification of form; they fit, indeed, almost as Cuvier describes, like the blades of a pair of scissors; the two teeth in advance of the carnassial in the upper jaw (*p.* 3, *p.* 2) in like manner are opposed to the same number of "fausses molaires" (*p.* 4, *p.* 3) in the under jaw, and the canine *c.* above plays upon the canine below; all seems straightforward and symmetrical, save that the little tubercular, *m.* 1, above has no opponent in the lower jaw. And, perhaps, the close observer might notice that, whilst the upper canine, *c.*, glides behind its homotype below, the first upper false molar (*p.* 2) passes anterior to the crown of the first false molar (*p.* 3) below; and that the second false molar and carnassial of the upper jaw are also a little in advance of those teeth in the under jaw when the mouth is shut.

In passing to the dentition of the Dog (*fig.* 580, III. Canis), formulised by Cuvier as: "fausses molaires $\frac{3-3}{4-4}$, carnassières $\frac{1-1}{1-1}$, tuberculeuses $\frac{2-2}{2-2}$; $= \frac{12}{14}$," it will be observed that here the first upper false molar (*p.* 1) differs from that in *Felis*, inasmuch as, when the mouth is shut, it preserves the same relative position to its opponent below (*p.* 1) which the upper canine does to the lower canine, and that the same may be said of the second and the third false molars; but that with regard to the carnassial above (*p.* 4) this tooth repeats the same relative position in regard to the fourth false molar below (*p.* 4), and not to that tooth, *m.* 1, which Cuvier regarded as the lower homotype of the carnassial; and, indeed, the more backward position of the lower carnassial is so slight that its significance might well be overlooked, more especially as the two succeeding tubercular teeth above were opposed to two similar tuberculars below. Cuvier therefore leaves us to conclude that the tooth which had no homotype or answerable opponent above was either the fourth "fausse molaire" below, or else the first. How unimportant size and shape are, and how significant relative position is in the determination of the homologies of teeth as of other parts, may be learnt before quitting the natural order of Carnivora; *e. g.* by the condition of the dental system in the Bear (*fig.* 580, II. Ursus). Here the lower tooth, *m.* 1, instead of presenting the carnassial character, and resembling in form the upper tooth (*p.* 4), which is the homologue of the upper carnassial in the dog, has a tubercular crown, and corresponds in size as well as shape with the upper tooth *m.* 1, to which it is almost wholly opposed, and with the same slight advance of position which we observe in the lower canine as compared with the upper one, and in the four lower premolars (*p.* 1, *p.* 2, *p.* 3, *p.* 4) as compared with their veritable homotypes above. F. Cuvier divides the molar series of the genus *Ursus* into "fausses molaires $\frac{3-3}{4-4}$, carnassières $\frac{1-1}{1-1}$, tuberculeuses $\frac{2-2}{2-2} = \frac{12}{14}$."

The tendency in every thinker to generalise and to recognise Nature's harmonies, has led him here to use the term "carnassière" in an arbitrary sense, and to apply it to a tooth above (*p.* 4), which he owns has such a shape and diminished size as would have led him to regard it as merely a false molar, but that the upper carnassial would then have entirely disappeared; and it has also led him to give the name "carnassière" to a tooth below, *m.* 1, which he, nevertheless, describes as having a tubercular and not a trenchant crown. In so natural a group as the true Carnivora it was impossible to overlook the homologues of the trenchant carnassials of the lion, even when they had become tubercular in the omnivorous bear; and Cuvier therefore, having determined and defined the teeth so called in the feline genus, felt compelled to distinguish them by the same names after they had lost their specific formal character. And if, indeed, he had succeeded in discovering the teeth which were truly answerable or homotypal in the upper and lower jaws, the term "carnassial" might have been retained as an arbitrary one for such teeth, and have been applied to their homologues in Man, the Ruminant, or the Pachyderm, where they are as certainly determinable as in those aberrant Carnivores, in which they have equally lost their sectorial shape. But the inconvenience of names indicative of such specialties of form will be very obvious when the term "tuberculeuses" comes to be applied to the three hindmost teeth in the *Hyænodon* (*fig.* 577.), which teeth answer to the broad crushing teeth, *m.* 1, *m.* 2, and *m.* 3, in the bear and some other existing Carnivora. The analogous term "molar," having a less direct or descriptive meaning, is therefore so much the better as the requisite arbitrary name of a determinate species of teeth.

Had Cuvier been guided in his determinations of the teeth by their mutual opposition in the closed mouth, and had studied them with this view in the Carnivora, with the dentition most nearly approaching to the typical formula, viz. the bear, he could then have seen that the three small and inconstant lower premolars (*p.* 1, *p.* 2, *p.* 3) were the homotypes of the three small and similarly inconstant premolars above; that the fourth false molar (*p.* 4) below, which, as he observes, "alone has the normal form," * was truly the homotype of the tooth above (*p.* 4), which he found himself compelled to reject from the class of "fausses molaires," notwithstanding it presented their normal form; that the tubercular tooth, *m.* 1, which he calls "carnassière" in the lower jaw, was the veritable homotype of his first "molaire tuberculeuse" above (*m.* 1), and that the tooth in the inferior series which had no answerable one above was his second "tuber-

* Dents des Mammifères, p. 111.

culeuse" (my *m.* 3), and not any of the four false molars. The true second tubercular above (*m.* 2) is, however, so much developed in the bear as to oppose both *m.* 2 and *m.* 3 in the lower jaw, and it might seem to include the homotypes of both those teeth coalesced. One sees with an interest such as only these homological researches could excite, that they were distinctly developed in the ancient *Amphicyon* (*fig.* 576.), which accordingly presents the typical formula. Thus, I repeat, the study of the relative position of the teeth of the bear might have led to the recognition of their real nature and homologies, and have helped to raise the mask of their extreme formal modifications, by which they are adapted to the habits of the more bloodthirsty Carnivora. But the truth is plainly and satisfactorily revealed when we come to trace the course of development and succession of these teeth. The weight which must ever attach itself to an opinion sanctioned by the authority of both the Cuviers, demands that a conclusion contrary to theirs, and which seems to be opposed by Nature herself in certain instances, should be supported by all the evidence of which such conclusion is susceptible.

I proceed, therefore, to show how, in the bear, my determinations of the teeth are established by their development, as well as by their relative position. As the question only concerns the molar series, the remarks will be confined to these. In the jaws of the young bear, figured in cut 581., the first premolar, *p.* 1, is the only one of the permanent series in place; similarity to *p.* 4 in the lower jaw (*fig.* 581, Ursus), to be veritably the last of the premolar series, and to agree not in shape only, but in every essential character, with the three preceding teeth called by Cuvier "fausses molaires." So, likewise, in the lower jaw, we see that the primitive deciduous series, *d.* 1, *d.* 2, *d.* 3, and *d.* 4, will be displaced by the corresponding premolars, *p.* 1, *p.* 2, *p.* 3, and *p.* 4; and that the tooth *m.* 1, called carnassière by Cuvier, in the lower jaw, differs essentially from that *p.* 4, so called in the upper jaw by being developed without any vertical predecessor or deciduous tooth.

The same law of development and succession prevails in the genus *Canis* (*fig.* 582.). Although the tooth *m.* 1 in the lower jaw has exchanged the tubercular for the carnassial form, it is still developed, as in the bear, behind the deciduous series, and independently of any vertical predecessor; and the tooth *p.* 4 above, although acquiring a relative superiority of size to its homologue in the bear, and more decidedly a carnassial form, is not the homotype of the permanent carnassial below, but of that premolar (*p.* 4) which is destined to displace the deciduous carnassial *d.* 4. The symbols sufficiently indicate the relations of the other teeth, and the conclusions that are to be drawn from them as to their homologies. It is interesting to observe in the deciduous, as well as in the permanent series, that the lower carnassial *d.* 4 is not the homotype of the upper one *d.* 3, but of the tooth which Cuvier calls the "tuberculeuse du lait," *d.* 4 in the upper jaw.

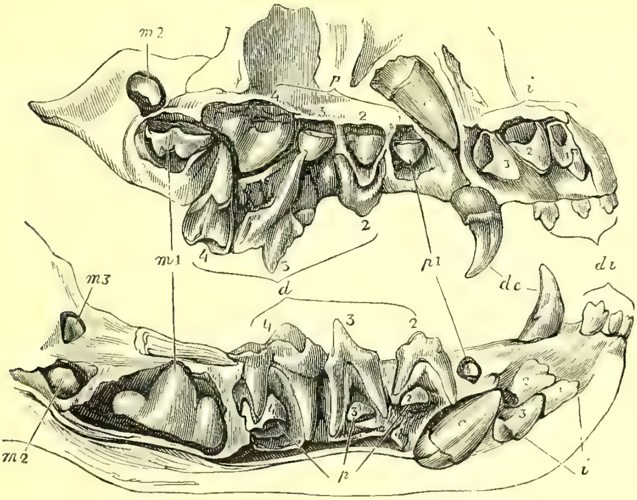
Fig. 581.

Deciduous and permanent dentition of the Bear (Ursus).

the other grinders in use are the deciduous molars, *d.* 2, *d.* 3, and *d.* 4; *d.* 2 will be displaced by *p.* 2, *d.* 3 by *p.* 3, and *d.* 4 by the tooth *p.* 4, which, notwithstanding its size and shape, Cuvier felt himself compelled to discard from the series of false molars, but which we now see is proved by its developmental relations to *d.* 4, as well as by its relative position and

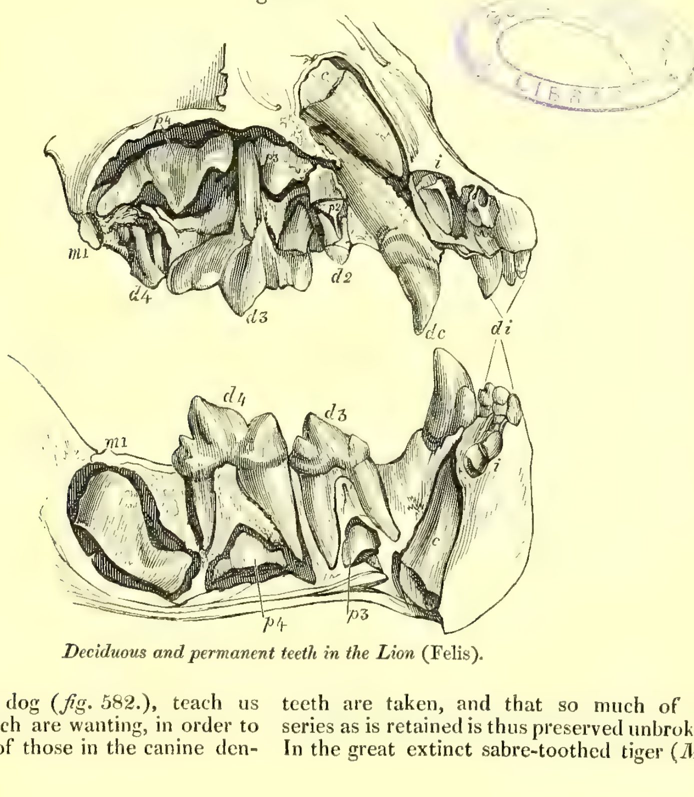
In the genus *Felis* (*fig.* 580.), the small permanent tubercular molar of the upper jaw, *m.* 1, has cut the gum before its analogue *d.* 4 of the deciduous series has been shed; but though analogous in function, this is not homologous with, or the precedent tooth to *m.* 1, but, as in the dog, to the great carnassially modified premolar, *p.* 4. In the lower jaw the tooth (*m.* 1), which is functionally analogous to the carnassial above, is also, as in the dog, the first of the true molar series, and the homotype of the little tubercular tooth (*m.* 1) above. And the homologies of the permanent teeth *p.* 4 above and *m.* 1 below, with those so symbolised in the dog (*fig.* 582.), teach us that the teeth which are wanting, in order to equal the number of those in the canine dentition, are *m.* 2 in the upper jaw, *m.* 2 and *m.* 3 in the lower jaw; *p.* 1 in the upper jaw, *p.* 1 and *p.* 2 in the lower jaw; thus illustrating the rule enuntiated above, that, when the molar series falls short of the typical number it is from the two extremes of such series that the teeth are taken, and that so much of the series as is retained is thus preserved unbroken. In the great extinct sabre-toothed tiger (*Ma-*

Fig. 582.



Deciduous and permanent teeth in the Dog (Canis).

Fig. 583.



Deciduous and permanent teeth in the Lion (Felis).

chairodus, *fig.* 580, VI.*), the series is still further reduced by the loss of *p.* 2 in the upper jaw.

That the student may test for himself the demonstration which the developmental characters above defined, yield of the true nature and homologies of the feline dentition, — the most modified of all in the terrestrial Carnivora, he is recommended to compare with nature the following details of the appearance and formation of the teeth in the common cat. In this species the deciduous incisors *d. i.* begin to appear between two and three weeks old; the canines *d. c.* next, and then the molars *d. m.* follow, the whole being in place before the sixth week. After the seventh month they begin to fall in the same order; but the lower sectorial molar *m.* 1, and its tubercular homotype above (*m.* 1) appear before *d.* 2, *d.* 3, and *d.* 4 fall. The longitudinal grooves are very faintly marked in the deciduous canines. The first deciduous molar (*d.* 2), in the upper jaw is a very small and simple one-fanged tooth; it is succeeded by the corresponding tooth of the permanent series, which answers to the second premolar (*p.* 2) of the hyæna and dog. The second deciduous molar (*d.* 3) is the sectorial tooth; its blade is trilobate, but both the anterior and posterior smaller lobes are notched, and the internal tubercle, which is relatively larger than in the permanent sectorial, is continued from the base of the middle lobe, as in the deciduous sectorial of the dog and hyæna; it thus typifies the form of the upper sectorial, which is retained in the permanent dentition of several Viverrine and Musteline species. The third or internal fang of the deciduous sectorial is continued from the inner tubercle, and is opposite the interspace of the two outer fangs. The Musteline type is further adhered to by the young Feline in the large proportional size of its deciduous tubercular tooth, *d.* 4. In the lower jaw, the first milk-molar (*d.* 3) is succeeded by a tooth (*p.* 3) which answers to the third lower premolar in the dog and civet. The deciduous sectorial (*d.* 4), which is succeeded by the premolar (*p.* 4), answering to the fourth in the dog, has a smaller proportional anterior lobe, and a larger posterior talon, which is usually notched; thereby approaching the form of the permanent lower sectorial tooth in the *Mustelidæ*.

In the article Carnivora (vol. i. p. 478.), the remarks on the teeth are limited chiefly to their physiological adaptations. A description of some of their more remarkable structures will here be given, according to the idea of the nature of the teeth above developed. The dental formula of the dog, jackal, wolf, and fox, is illustrated in *fig.* 580, III. Canis.

* *Machairodus*, from μάχαιρα, a sabre; and ὀδοὺς, a tooth. This generic name was imposed by Dr. Kaup on the extinct animal which was armed with canine teeth, like that figured in *fig.* 580, VI. Such teeth, long, compressed, falciform, sharp-pointed, and with anterior and posterior finely-serrated edges, were first discovered in tertiary strata in Italy and Germany, and were referred by Cuvier to a species of bear, under the name of *Ursus cultridens*. Fossil canines of this genus have been found in Kent's Hole cave, Torquay.

In the *Megalotis*, or Long-eared Fox (*Otocyon*, Licht.), the deviation from the typical dentition of the *Canidæ* is effected by excess of development; two additional true molars being present on each side of the upper, and one on each side of the lower jaw, in the permanent series of teeth; and an approach is made by the modified form of the sectorial molar and of some of the other teeth to the dentition of the *Viverridæ*. This family of Carnivora, which comprehends the Civets, Genets, Ichneumons, Musangs, Surikates, and Mangues, is characterised, with few exceptions, by the following formula: — *i.* $\frac{3-3}{3-3}$; *c.* $\frac{1-1}{1-1}$; *p.* $\frac{4-4}{4-4}$; *m.* $\frac{2-2}{2-2}$: = 40. It differs from that of the genus *Canis* by the absence of a tubercular tooth (*m.* 3) on each side of the lower jaw; but, in thus making a nearer step to the typical carnivorous dentition, the *Viverridæ*, on the other hand, recede from it by the less trenchant and more tubercular character of the sectorial teeth, as is shown in the figures of the teeth of the *Viverra indica*, in my "Odontography," pl. 126. figs. 1, 2, and 3.

The canines are more feeble, and their crowns are almost smooth; the premolars, however, assume a formidable size and shape in some aquatic species, as those of the sub-genus *Cynogale*, in which their crowns are large, compressed, triangular, sharp-pointed, with trenchant and serrated edges, like the teeth of certain sharks, (whence the name *Squalodon*, proposed for one of the species), and well adapted to the exigencies of quadrupeds subsisting principally on fish: the opposite or obtuse, thick form of the premolars is manifested by some of the Musangs, as *Paradoxurus auratus*. The upper sectorial tooth, *p.* 4, is characterised by having its inner tubercle larger, the middle conical division of the blade thicker, and the posterior one smaller than in the genus *Canis*. This tooth advances to beneath the ant-orbital foramen in the Musangs (*Paradoxurus*): it is situated farther back in the Civets and Genets, in which the blade of the sectorial is sharper. This shows that relative position to the zygomatic or molar process of the maxillary is not a good character.

In the lower jaw the sectorial tooth (*m.* 1) manifests its true molar character by the presence of an additional pointed lobe on the inner side of the two lobes forming the blade at the fore-part of the crown: the posterior, low, and large lobe of the tooth being also tri-tuberculate, as in the dog. The last molar (*m.* 2) has an oval crown with four small tubercles, resembling the penultimate lower molar in the dog, with which it corresponds.

The deciduous dentition consists, in the Viverrine family, of: incisors $\frac{3-3}{3-3}$; canines $\frac{1-1}{1-1}$; molars $\frac{3-3}{3-3}$: = 28. If the first permanent premolar has any predecessor, it must be rudimental and disappear early in both jaws; the second premolar displaces the first normally developed deciduous molar; the third upper premolar displaces and succeeds the deciduous sectorial, which has a sharper and more compressed blade, and a relatively smaller internal tubercle, than the permanent sectorial. This tooth displaces the last deciduous molar, which is a tubercular tooth, resembling in form the first of the two upper permanent tuberculars; these coming into place without pushing out any predecessors, enter into the category of true molar teeth. In the lower jaw the third premolar displaces the deciduous sectorial, which has three trenchant lobes and a relatively smaller posterior talon than the permanent sectorial. The fourth premolar displaces the third or tubercular milk-molar. The permanent sectorial and tubercular molars displace no predecessors, and are therefore *m.* 1 and *m.* 2.

The first premolar, *p.* 1, is not developed at any period in the Mangues (*Crossarchus*), the Suricates (*Ryzæna*), or the *Mangusta paludinosa*; these Viverrines, therefore, retain throughout life more of the immature characters of the family, and in the same degree approach in the numerical characters of their dentition to the more typical Carnivora.

The alternate interlocking of the crowns of the teeth of the upper and lower jaws, which is their general relative position in the Carnivora, is well marked in regard to the premolars of the *Viverridæ* (*fig.* 580, IV.): as the lower canine is in front of the upper, so the first lower premolar rises into the space between the upper canine and first upper premolar; the fourth lower premolar in like manner fills the space between the third upper premolar (*p.* 3) and the sectorial tooth (*p.* 4), playing upon the anterior lobe of the blade of that tooth which indicates by its position, as by its mode of succession, that it is the fourth premolar of the upper jaw. The first true molar below, modified as usual in the *Carnivora* to form the lower sectorial, sends the three tubercles of its anterior part to fill the space between the sectorial (*p.* 4) and the first true molar (*m.* 1) above. In the Musangs the lower sectorial is in more direct opposition to its true homotype, the first tubercular molar in the upper jaw; and these Indian *Viverridæ* (*Paradoxuri*) are the least carnivorous of their family, their chief food consisting of the fruit of palm-trees, whence they have been called "Palm-cats."

Hyæna.—The dentition of this genus presents a nearer approach to the strictly carnivorous type by the reduction of the tubercular molars to a single minute tooth on each side of the upper jaw, the inferior molars being all conical or sectorial teeth: the molar teeth in both jaws are larger and stronger, and the canines smaller in proportion than in the Feline species, from the formula of which the dentition of the hyæna differs numerically only in the retention of an additional premolar tooth, *p.* 1 above and *p.* 2 below, on each side of both jaws. The dental formula of the genus *Hyæna* is:—$in.\ \frac{3-3}{3-3},\ c.\ \frac{1-1}{1-1},\ pm.\ \frac{4-4}{3-3},\ m.\ \frac{1-1}{1-1} := 34.$ The crowns of the incisors form almost a straight tranverse line in both jaws, the exterior ones, above, being much larger than the four middle ones, and extending their long and thick inserted base further back: the crown of the upper and outer incisor (*i.* 3.) is strong, conical, recurved, like that of a small canine, with an anterior and posterior edge, and a slight ridge along the inner side of the base. The four intermediate small incisors have their crown divided by a transverse cleft into a strong anterior, conical lobe, and a posterior ridge, which is notched vertically; giving the crown the figure of a trefoil. The lower incisors gradually increase in size from the first to the third; this and the second have the crown indented externally; but they have not the posterior notched ridge like the small upper incisors; the apex of their conical crown fits into the interspace of the three lobes of the incisor above. The canines have a smooth convex exterior surface, divided by an anterior and posterior edge from a less convex inner side: this surface is almost flat and of less relative extent in the inferior canines. The first premolar above (*p.* 1) is very small, with a low, thick, conical crown: the second presents a sudden increase of size, and an addition of a posterior and internal basal ridge to the strong cone. The third premolar exhibits the same form on a still larger scale, and is remarkable for its great strength. The posterior part of the cone of each of these premolars is traversed by a longitudinal ridge. The fourth premolar is the carnassial tooth, and has its long blade divided by two notches into three lobes, the first a small thick cone, the second a long and compressed cone, the third a horizontal sinuous trenchant plate: a strong triedral tubercle is developed from the inner side of the base of the anterior part of the crown. The single true molar of the upper jaw (*m.* 1) is a tubercular tooth of small size: transversely oblong in the *Hyæna vulgaris* and *H. fusca*; smaller and sub-circular in the *Hyæna crocuta*; still smaller and implanted by a single fang in the *Hyæna spelæa*: in all the existing species of Hyæna it has two fangs. The first premolar of the lower jaw (*p.* 2) fits into the interspace between the first and second premolars above, and answers, therefore, to the second lower premolar in the *Viverridæ*: it is accordingly much larger than the first (*p.* 1) above; it has a ridge in the fore-part of its cone, and a broad basal talon behind. The second (*p.* 3) is the largest of the lower premolars, has an anterior and a posterior basal ridge, with a vertical ridge ascending upon the fore as well as the back part of the strong rounded cone: the third premolar (*p.* 4.) is proportionably less in the *Hyæna crocuta* than in the *H. vulgaris*: its posterior ridge is developed into a small cone; the last tooth (*m.* 1) is the sectorial, and consists almost entirely of a blade divided by a vertical fissure into two sub-equal compressed pointed lobes: the points are less produced than in the Felines, but the lower sectorial of the hyæna is better distinguished by the small posterior basal talon, from which a ridge is continued along the inner side of the base, and is slightly thickened at the fore-part of the crown. According to the relative position of the crowns of the premolars the third below ought to be the last, being analogous to the fourth in the *Viverridæ*, and the sectorial should be first true molar: we shall find this view confirmed by the test of the mode of succession of the permanent teeth. But the mode of implantation of the premolar and molar teeth may first be noticed. The first upper premolar has but one fang; the second and third have each two; the sectorial tooth has three, the two anterior ones on the same tranverse line, the inner one supporting the tubercle. The lower premolars and sectorial have each two fangs, there being none truly answering to the first above: the anterior root of the lower (*p.* 1) sectorial tooth is very strongly developed in the great extinct Cave-Hyæna.

The deciduous teeth consist of:—$i. \frac{3-3}{3-3}$, $c. \frac{1-1}{1-1}$, $m. \frac{3-3}{3-3}$, = 28. The figure of the skull of the young *Hyæna crocuta* in the posthumous edition of the "Ossemens Fossiles," 8vo. 1836, pl. 190, fig. 3, shows that stage when the correspondence with the formula of the genus *Felis* is completed by the appearance, in the upper jaw, of a small premolar in the interspace between the canine and first molar of the deciduous series: but this appearance is due to the apex of the first permanent premolar which cuts the gum before any of the normal deciduous teeth are shed: whether it is preceded, as in the dog, by a deciduous germ-tooth in the fœtus, I know not. The first normal deciduous molar is two-fanged, and has a more compressed and consequently more carnivorous crown than that of the second permanent premolar by which it is succeeded. The second deciduous molar is the sectorial tooth: the inner tubercle is continued from the base of the middle lobe, and thus resembles the permanent sectorial of the Glutton (*Gulo*) and many other *Mustelidæ;* the deciduous tubercular molar is relatively larger than in the adult *Hyæna*, and offers another feature of resemblance to the permanent dentition of the Glutton. It is also worthy of remark that the exterior incisor of the upper jaw is not only absolutely, but relatively smaller in the immature than in the adult dentition of the hyæna, and again illustrates the resemblance to the more common type of dentition in the Carnivora.

The first and second deciduous molars below have more compressed conical crowns than their successors: the third deciduous molar is the sectorial tooth, and, again, as in *Gulo*, has a better developed hinder tubercle than the permanent sectorial; it is not displaced by this tooth, but, as in other Carnivora, by a premolar of more simple character. The permanent sectorial is developed posteriorly, and rises, like other true molars, without displacing a deciduous predecessor.

The permanent dentition of the *Hyæna*, as of other genera or families of the Carnivora, assumes those characteristics which adapt it for the peculiar food and habits of the adult, and mark the deviation from the common type, which always accompanies the progress to maturity. The most characteristic modification of this dentition is the great size and strength of the molars as compared with the canines, and more especially the thick and strong conical crowns of the second and third premolars in both jaws, the base of the cone being belted by a strong ridge which defends the subjacent gum.* This form of tooth is especially adapted for gnawing and breaking bones, and the whole cranium has its shape modified by the enormous development of the muscles which work the jaws and teeth in this operation.† Adapted to obtain its food from the coarser parts of animals which are left by the nobler beasts of prey, the hyæna chiefly seeks the dead carcass, and bears the same relation to the lion which the vulture does to the eagle. In consequence of the quantity of bones which enter into its food, the excrements consist of solid balls of a yellowish white colour, and of a compact earthy fracture. Such specimens of the substance, known in the old *Materia Medica* by the name of "album græcum," were discovered by Dr. Buckland in the celebrated ossiferous cavern at Kirkdale. They were recognised at first sight by the keeper of a menagerie, to whom they were shown, as resembling both in form and appearance the fœces of the spotted Hyæna; and, being analysed by Dr. Wollaston, were found to be composed of the ingredients that might be expected in fœcal matter derived from bones, viz. phosphate of lime, carbonate of lime, and a very small proportion of the triple phosphate of ammonia and magnesia. This discovery of the coprolites of the hyæna formed, perhaps, the strongest of the links in that chain of evidence by which Dr. Buckland proved that the cave at Kirkdale, in Yorkshire, had been, during a long succession of years, inhabited as a den by hyænas, and that they dragged into its recesses the other animal bodies, whose remains, splintered and bearing marks of the teeth of the hyæna, were found mixed indiscriminately with their own.

* An eminent civil engineer, to whom I showed the jaw of a hyæna, observed that the strong conical tooth, with its basal ridge, was a perfect model of a hammer for breaking stones for roads.

† "The strength of the hyæna's jaw is such that, in attacking a dog, he begins by biting off his leg at a single snap." Buckland, "Reliquiæ Diluvianæ," p. 23.

The dentition of the Weasel tribe (*Mustelidæ*) is illustrated (in *fig.* 580, IV.) by that of the Otter, *Mustela Lutra* of Linnæus, and which is essentially a great aquatic Weasel or Polecat; its dental formula is $i.\ \frac{3-3}{3-3}$, $c.\ \frac{1-1}{1-1}$, $p.\ \frac{4-4}{3-3}$, $m.\ \frac{1-1}{2-2}$: = 36. In the Martin cats (*Mustela martes*, L.), the little homotype of *p.* 1 above is present in the lower jaw; in the bloodthirsty stoats and weasels, *p.* 1 is absent in both jaws; as it is likewise in the great sea-otter (*Enhydra*), in which also the two middle incisors are wanting in the lower jaw. In this animal the second premolar (*p.* 3) has a strong obtuse conical crown, double the size of that of *p.* 2; the third premolar (*p.* 4) is more than twice the size of *p.* 3, and represents the upper carnassial or sectorial strangely modified; the two lobes of the blade being hemispheric tubercles. The last tooth, *m.* 1, has a larger crown than the sectorial, and is of a similar broad crushing form. In the lower jaw the molar series are not separated by any interspace: the first and second premolars have oblique obtuse conical crowns. The third premolar (*p.* 4) is more than twice the size of the second (*p.* 3) and supports a large anterior hemispheric protuberance with a small internal tubercle and a posterior basal ridge. The first true molar has an oblong quadrate crown with an anterior small tubercle, a larger and more prominent inner one, and the rest of the broad horizontal surface undulating. The second true molar has a transversely elliptical crown depressed in the centre. When the teeth are in apposition, the anterior third of the first true molar below is applied to the inner tubercle of the last premolar above; the rest of its crown plays upon that of its homotype, the first true molar in the upper jaw, leaving a small part of that tooth to receive the appulse of the second true molar below, which has no corresponding tooth in the upper jaw.

The *Mustelidæ* present great constancy in regard to the number of their true molar teeth; with one exception, the Ratel (*Mellivora*), in which *m.* 2 is absent below, they have one true molar on each side of the upper jaw, and two on each side of the lower jaw; the second of these has always a broad tubercular crown, like the one above. The upper true molar is supported by one inner, and sometimes by one (*Putorius*, *Gulo*), sometimes two (*Mustela*, *Lutra*, *Melphitis*), outer fangs. The second true molar below is also tubercular, but has a single fang. The crown of the first true molar below offers many gradations from the sectorial type, as manifested in *Putorius* and *Gulo*, to the tubercular type, as in the Taira, Ratel, and sea-otter. The principal varieties occur, as usual, in the comparatively less important premolars: in the Martins and Gluttons, they are as numerous as in the dog; the first, in both jaws, being implanted by a single fang; the rest by two, with the exception of the last above, which has three roots. In the otter, we find the first premolar removed from the lower jaw; and the second (now the first) shows its true homology by its double implantation, as well as by the position of its crown behind the first in the upper jaw (*p.* 1). In the Stoats, Skunks, and Ratels, the premolar series is further reduced by the loss of the anterior tooth (*p.* 1) in both jaws, and by the diminution of the size of *p.* 2, which thus becomes the first in both jaws, and which is also now implanted by a single fang. In a South American Skunk, the second premolar disappears in the upper jaw, leaving there only the homologues of the third and fourth of the typical formula, *p.* 4 being always the sectorial in the *Mustelidæ*, as in other terrestrial Carnivora. This tooth, under all its modifications, retains the blade with the lobe, corresponding to the middle one in the feline sectorial, generally well developed and sharp-pointed; the differences are principally manifested by the proportions of the inner tubercle, and the relative size of the third root supporting it. But the upper sectorial, being a premolar, and therefore requiring less modification of the crown to adapt it for its special functions, manifests a more limited extent of variety than the lower sectorial, which, being a true molar, requires greater modification of the typical form of its crown to fit it for playing upon the sectorial blade of *p.* 4 above.

Melidæ.—In this sub-family I comprise the European Badger (*Meles*), the Indian Badger (*Arctonyx*), and the American Badger (*Taxidea*); which, with respect to their dentition, stand at the opposite extreme of the *Mustelidæ* to that occupied by the predaceous Weasel, and manifest the most tuberculate and omnivorous character of the teeth. The formula is:—$i.\ \frac{3-3}{3-3}$; $c.\ \frac{1-1}{1-1}$; $p.\ \frac{3-3}{4-4}$; $m.\ \frac{1-1}{2-2}$: = 30.

The canines are strongly developed, well pointed, with a posterior trenchant edge; they are more compressed in *Arctonyx* than in *Meles*. The first lower premolar (*p.* 1) is very small, single-fanged, and, generally, soon lost. The first above, corresponding with the second in the dog, is also small, and implanted by two connate fangs. The second upper premolar (*p.* 3) has a larger, but simple, sub-compressed conical crown, and is implanted by two fangs: the third (*p.* 4) repeats the form of the second on a larger scale, with a better developed posterior talon, and with the addition of a tri-tuberculate low flat lobe, which is supported by a third fang: the outer pointed and more produced part of this tooth represents the blade of the sectorial tooth and the entire crown of the antecedent premolars. The true molar in *Meles* (*m.* 1) is of enormous size compared with that of any of the preceding Carnivora: it has three external tubercles, and an extensive horizontal surface traversed longitudinally by a low ridge, and bounded by an internal belt, the *cingulum* of Illiger: this tooth has a similarly shaped, but relatively smaller, crown in *Arctonyx*.* The second premolar below (*p.* 2) is commonly the first, through the early loss of the minute one in front; its fangs are usually connate, as in its homotype above. The third and fourth premolars slightly increase in size, have simple compressed conical crowns, and two fangs each. The first true molar below (*m.* 1) now retains little of its sectorial character, the blade being represented only by the two anterior small, compressed pointed lobes; behind these, the crown expands into an oval grinding surface, narrower in *Arctonyx* than in *Meles*, supporting three tubercles and a posterior tuberculate ridge: it has generally two principal roots and a small intermediate accessory fang, as in the otter. The second molar (*m.* 2), which terminates the series below, is of small size, and has a rounded flat crown, depressed in the centre, and with two small external tubercles; its two short fangs are connate. In the Labrador Badger, the last premolar has a larger relative size, the part corresponding with the blade of the sectorial, is sharper and more produced, and the internal tubercle has two lobes; the succeeding molar tooth is reduced in size, and its crown presents a triangular form. The first true molar below has its sectorial lobes better developed: these differences give the North American badgers a more carnivorous character than is manifested by the Indian or European species.

Sub-Ursidæ.—In other allied genera, which, like the badgers, have been grouped, on account of the plantigrade structure of their feet, with the bears, a progressive approximation is made to the type of the dentition of the Ursine species. The first true molar below soon loses all its sectorial modification, and acquires its true tubercular character: and the last premolar above becomes more directly and completely opposed to its homotype in the lower jaw. The Racoon (*Procyon* †) and the Coati (*Nasua*) present good examples of these transitional modifications; they have the complete number of premolar teeth, the dental formula being, $i.\frac{3-3}{3-3}$, $c.\frac{1-1}{1-1}$, $p.\frac{4-4}{4-4}$, $m.\frac{2-2}{2-2}:=40$. The development of the inner part of the crown of the last upper premolar, which constitutes the tubercle of the sectorial tooth, now produces two tubercles on a level with the outer ones which represent the blade; and the opposite premolar below (*p.* 4), which is the true homotype of the modified sectorial above, begins to acquire a marked increase of breadth and accessory basal tubercles. All the lower premolars, as well as the true molars, have two fangs; the three first premolars above have two fangs, the fourth has three, like the two true molars above.

The dental formula of the Indian Benturong (*Arctictis*) and Kinkajou (*Cercoleptes*) is $i.\frac{3-3}{3-3}$, $c.\frac{1-1}{1-1}$, $p.\frac{3-3}{3-3}$, $m.\frac{2-2}{2-2}:=36$.

Phocidæ.—We have seen a tendency to deviate from the ferine number of the incisors in the most aquatic and piscivorous of the Musteline quadrupeds, viz. the sea-otter (*Enhydra*), in which species the two middle incisors of the lower jaw are not developed in the permanent dentition. In the family of true seals, the incisive formula is further reduced, in some species even to zero in the lower jaw, and it never exceeds $\frac{3-3}{2-2}$. All the *Phocidæ* possess powerful canines; only in the aberrant walrus (*Trichechus*) are they absent in the lower jaw, but this is compensated by the singular excess of development which they manifest in the upper jaw. In the pinnigrade, as in the plantigrade, family of Carnivores we find the teeth which correspond to true molars more numerous than in the digitigrade species, and even occasionally rising to the typical number, three on each side; but this, in the seals, is manifested in the upper and not, as in the bears, in the lower jaw. The entire molar series usually includes five, rarely six teeth on each side of the upper jaw, and five on each side of the lower jaw, with crowns, which vary little in size or form in the same individual; they are supported in some genera, as the Eared Seals (*Otariæ*) and Elephant Seals (*Cystophora**), by a single fang; in other genera † by two fangs, which are usually connate in the first or second teeth; the fang or fangs of both incisors, canines and molars, are always remarkable for their thickness, which commonly surpasses the longest diameter of the crown. The crowns are most commonly compressed, conical, more or less pointed, with the "cingulum" and the anterior and posterior basal tubercles more or less developed; in a few of the largest species they are simple and obtuse, and particularly so in the walrus, in which the molar teeth are reduced to a smaller number than in the true seals.‡ In these the line of demarcation between the true and false molars is very indefinitely indicated by characters of form or position; but, according to the instances in which a deciduous dentition has been observed, the first three permanent molars in both jaws succeed and displace the same number of milk molars, and are consequently *premolars;* occasionally, in the seals with two-rooted molars, the more simple character of the premolar teeth is manifested by their fangs being connate, and in the *Stenorhynchus serridens* the more complex character of the true molars is manifested in the crown. There is no special modification of the crown of any tooth by which it can merit the name of a

* See Odontography, pl. 128, *fig.* 13, *m.* 1.
† Ib. pl. 129, *fig.* 7. ‡ Ib. *figs.* 8—13.

* Odontography, pl. 132, *fig.* 7.
† Ib. *figs.* 1—4.
‡ The relation of *Trichechus* to the *Phocidæ* is analogous to that of *Machairodus* to the *Felidæ*, and also, in the simplification of the molars, to that of *Proteles* to *Canidæ*.

"sectorial" or "carnassial;" but we may point with certainty to the third molar above and the fourth below as answering to those teeth which manifest the sectorial character in the terrestrial Carnivora.

The coadaptation of the crowns of the upper and lower teeth is more completely alternate than in any of the terrestrial Carnivora, the lower tooth always passing into the interspace anterior to its fellow in the upper jaw. In the genus *Phoca* proper (*Calocephalus*, Cuv.) typified by the common seal (*Ph. vitulina*), the dental formula is, $i.\ \frac{3-3}{2-2}$, $c.\ \frac{1-1}{1-1}$, $p.\ \frac{3-3}{3-3}$, $m.\ \frac{2-2}{2-2}:=34$. The forms and proportions of these teeth are shown in Pl. 132, *fig.* 1., of my "Odontography." The first tooth above and below presents a complete confluence of the fangs; they are separated from the second above; but below they sometimes do not become free before the fourth, and sometimes the two roots are distinct in the third and second molars. In the *Phoca anellata* Nills., the principal cusp of the molar teeth is complicated with anterior and posterior smaller cusps, sometimes one in number in the upper molars; the anterior accessory cusp is sometimes wanting in the first, and is rudimentary in the rest; but usually there are two small cusps behind the principal one, and in the three or four posterior molars in the lower jaw there are sometimes two small cusps before and two behind the principal one.*

In the *Phoca caspica* the upper molars have commonly one accessory cusp before and one behind the principal lobe; the lower molars have one accessory cusp before and two behind.

In the *Phoca grœnlandica* the upper molars have no anterior basal cusp and only one behind; the lower molars have two cusps behind and one in front, except the first, which resembles that above, and, like it, has connate fangs.

The condition of the molar teeth is nearly the same in the *Phoca barbata*, but the crowns are rather thicker and stronger, and the three middle ones above have two posterior basal cusps feebly indicated, the same being more strongly marked in the four last molars below.

The following genera of seals with double-rooted molars (*Pelagius* and *Stenorhynchus*) have four incisors above as well as below, *i. e.* $\frac{2-2}{2-2}$. An upper view of the molar teeth in the Hooded Seal of the Mediterranean (*Pelagius monachus*) is given in my Odontography, Pl. 132. *fig.* 3., as when they are worn down in an old specimen; the crowns are thick, obtuse, sub-compressed, with a well developed cingulum, a principal lobe and an anterior and posterior accessory basal lobule; the fangs are connate in the first tooth both above and below.

The allied sub-genus (*Ommatophoca*) of seals of the southern hemisphere has six molar teeth on each side of the upper, and five on each side of the lower jaw, with the principal lobe of the crown more incurved. The two first molars above are closely approximated, but this may prove to be a variety.

In the *Stenorhynchus* the jaws are more slender and produced, and the molar teeth are remarkable for the long and slender shape of the principal lobe, and of the accessory basal cusps. The incisors have sharp conical recurved crowns, like the canines, and the external ones in the upper jaw are intermediate in size between the canines and the middle incisors.

In the *Stenorhynchus leptonyx* each molar tooth in both jaws is trilobed, the anterior and posterior accessory curving towards the principal one, which is bent slightly backwards; all the divisions are sharp-pointed, and the crown of each molar thus resembles the trident or fishing-spear; the two fangs of the first molar in both jaws are connate. In *Stenorhynchus serridens* the three anterior molars on each side of both jaws are four-lobed, there being one anterior and two posterior accessory lobes; the remaining posterior molars (true molars) are five-lobed, the principal cusp having one small lobe in front, and three developed from its posterior margin; the summits of the lobes are obtuse, and the posterior ones are recurved like the principal lobe. Sometimes the third molar below has three instead of two posterior accessory lobes. Occasionally, also, the second, as well as the first molar above, has it fangs connate; but the essentially duplex nature of the seemingly single fang, which is unfailingly manifested within by the double pulp-cavity, is always outwardly indicated by the median longitudinal opposite indentations of the implanted base. These slight and unessential varieties, presented by the specimens of the Saw-toothed Sterrink (*Stenorhynchus serridens*) brought home by the enterprising Naturalist of Sir J. Ross's Antarctic expedition, accord with the analogous varieties noticed by the best observers of the seals of our neighbouring seas, as, for example, Nillson.

The Grey Seal (*Halichœrus gryphus*) of our own seas begins, by the extension of the connate condition of the two roots through a greater proportion of the molar series, to manifest a transition to the family of seals with true single-rooted molars; the formula of this genus is, $i.\ \frac{3-3}{2-2}$, $c.\ \frac{1-1}{1-1}$, $p.\ \frac{3-3}{3-3}$ $m.\ \frac{2-2}{2-2}:=34$. The four middle upper incisors are close set, with pointed recurved crowns; the lateral ones are much larger and laniariform; the canines have moderate crowns, with a sharp ridge before and behind. The

* Nillson, in Wiegmann's Archiv. 1841, 313. I notice these varieties of the crown, in connection with analogous ones in the fangs of the teeth of the same species, to show the inadequacy of such characters as marks of subgeneric distinction.

crowns of the molar teeth are conical, sub-compressed longitudinally and finely grooved, with an anterior and posterior edge; those below have generally a slight notch at the fore and back part of the base. The first molars, both above and below, are the smallest, with a simple crown and a single ventricose fang; the second and third above, and the second, third, and fourth below, have two connate roots; the two roots are commonly distinct in the remaining posterior molars: all the roots are very thick.

In the genus *Otaria* the dental formula is, $i. \frac{3-3}{2-2}, c. \frac{1-1}{1-1}, p. \frac{3-3}{3-3}, m. \frac{3-3}{2-2} = 36.$ The two middle upper incisors are small, sub-compressed, with the crown transversely notched; the simple crowns of the four incisors below fit into these notches: the outer incisors above are much larger, with a long pointed conical crown, like a small canine. The true canine is twice as large as the adjoining incisor, and is rather less recurved. The molars have each a single fang; the crown is conical, sub-compressed, pointed; in the two last recurved, with a basal ridge or "cingulum," broadest within; but, in the *Otaria jubata*, the molars have a pointed cusp developed from the fore-part, and in the last two molars also from the back part of the crown. In some species, as the *Otaria lobata* (*Phoca lobata*, Fischer), the single molar is not developed in the upper jaw, and the outer incisors above are not so large: in this species a thick plicated cingulum belts the base of each molar and developes a small tubercle from its fore-part in the molars of the lower jaw; the crown of the last molar above is notched.

In the great proboscidian and hooded Seals (*Cystophora*), the incisors and canines still more predominate in size over the molars; but the incisors are reduced in number, the formula here is: $i. \frac{2-2}{1-1}, c. \frac{1-1}{1-1}, p. \frac{3-3}{3-3}, m. \frac{2-2}{2-2} := 30.$ All the molars are single-rooted, and all the incisors are laniariform. The two middle incisors above and the two below are nearly equal; the outer incisors above are larger. The canines are still more formidable, especially in the males; the curved root is thick and subquadrate. The crowns of the molar teeth are short, sub-compressed, obtuse; sometimes terminated by a knob and defined by a constriction or neck from the fang; the last is the smallest.

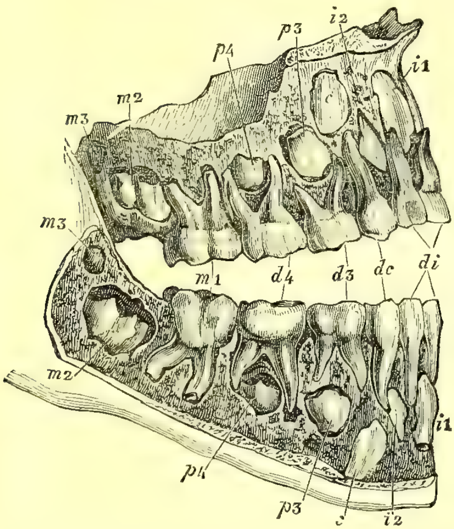
In the Walrus (*Trichechus rosmarus*), the normal incisive formula is transitorily represented in the very young animal, which has three teeth in each intermaxillary bone and two on each side of the fore-part of the lower jaw; they soon disappear, except the outer pair above, which remain close to the intermaxillary suture, on the inner side of the sockets of the enormous canines, and seem to commence the series of small and simple molars which they resemble in size and form. In the adult there are usually three molars or premolars on each side above, behind the permanent incisor, and four similar teeth on each side of the lower jaw; the anterior one passing into the interspace between the upper incisor and the first molar, and therefore being the homotype of the molar. In a young walrus's skull with canine tusks eight inches long, I have seen a fourth upper molar, (fifth including the incisor), of very small size, about a line in breadth, lodged in a shallow fossa of the jaw, behind the three persistent molars. The crowns of these teeth must be almost on a level with the gums in the recent head; they are very obtuse and worn obliquely from above down to the inner border of their base. The molars of the lower jaw are rather narrower from side to side than those above, and are convex or worn upon their outer side. Each molar has a short, thick, simple and solid root.

The canines are developed only in the upper jaw, but are of enormous size, descending and projecting from the mouth, like tusks, slightly inclined outwards and bent backwards; they present an oval transverse section, with a shallow longitudinal groove along the inner side, and one or two narrower longitudinal impressions upon the outer side; the base of the canine is widely open, its growth being uninterrupted.

The food of the walrus consists of sea-weed and bivalves; the molars are well adapted to break and crush shells; and fragments of a species of *Mya* have been found, with pounded sea-weed, in the stomach. The canine tusks serve as weapons of offence and defence, and to aid the animal in mounting and clambering over blocks of ice. For their composition and microscopic structure I must refer to my "Odontography," p. 511. *et seq.*

The precise determination of the teeth in the walrus and some other kinds of seals, still awaits the opportunity of examining very young specimens with the deciduous series, which is very early lost. When the clew is afforded by the opportunity of studying the development and succession of the teeth, it infallibly conducts us to the true knowledge of the nature, both of the teeth which are retained, and of those that are wanting to complete the typical number. We have availed ourselves of this in deciphering the much modified dentition of the genus *Felis;* and the same clew will guide us to a similar satisfactory knowledge of the nature and homologies of the teeth in the human species. The discovery, by the great poet Göthe, of the limits of the premaxillary bone in man leads to the determination of the incisors, which are reduced to two on each side of both jaws: the contiguous tooth shows by its shape, as well as position, that it is the canine, and the characters of size and shape have also served to divide the remaining five teeth in each lateral series into two bicuspids and three molars. In this instance, as in the dentition of the bear, the secondary characters conform with the essential ones. But since we have seen of how little value shape or size are, in the order Carnivora, in the determination of the exact homologies of the teeth, it is satisfactory to know that the more constant and important character of development gives the requisite certitude as to the nature of the so-called bicuspids in the human subject. In *fig.* 584., the condition of the

Fig. 584.



Deciduous and permanent teeth of a Child (Homo).

teeth is shown in the jaws of a child of about six years of age. The two incisors on each side (*di.*) are followed by a canine, *dc.*, and this by three teeth having crowns resembling those of the three molar teeth of the adult. In fact, the last of the three is the first of the permanent molars; it has pushed through the gum, like the two molars which are in advance of it, without displacing any previous tooth, and the substance of the jaw contains no germ of any tooth destined to displace it: it is therefore, by this character of its development, a true molar, and the germs of the permanent teeth, which are exposed in the substance of the jaw between the diverging fangs of the molars, *d.* 3 and *d.* 4, prove those molars to be temporary, destined to be replaced, and prove also that the teeth about to displace them are premolars. According, therefore, to the rule previously laid down, we count the permanent molar in place the first of its series (*m.* 1), and the adjoining premolar as the last of its series, and consequently the fourth of the typical dentition, or *p.* 4.

We are thus enabled, with the same scientific certainty as that whereby we recognise in the middle toe of the foot the homologue of that great digit which forms the whole foot and is encased by the hoof in the horse, to point to *p.* 4, or the second bicuspid in the upper jaw, and to *m.* 1, or the first molar in the lower jaw of man, as the homologues of the great carnassial teeth of the lion and tiger. We also conclude that the teeth which are wanting in man to complete the typical molar series, are the first and second premolars, the homologues of those marked *p.* 1 and *p.* 2 in the bear. The characteristic shortening of the maxillary bones required this diminution of the number of their teeth, as well as of their size, and of the canines more especially; and the still greater curtailment of the premaxillary bone is attended with a diminished number and an altered position of the incisors. One sees, indeed, in the carnivorous series, that a corresponding decrease in the number of the premolars is concomitant with the shortening of the jaws. Already in the *Mustelidæ*, (*fig.* 580., IV), *p.* 1 below is abrogated; in *Felis* also above, with the further loss of *p.* 2 in the lower jaw; the true molars being correspondingly reduced in these strictly flesh-eating animals, but taken away from the back part of their series.

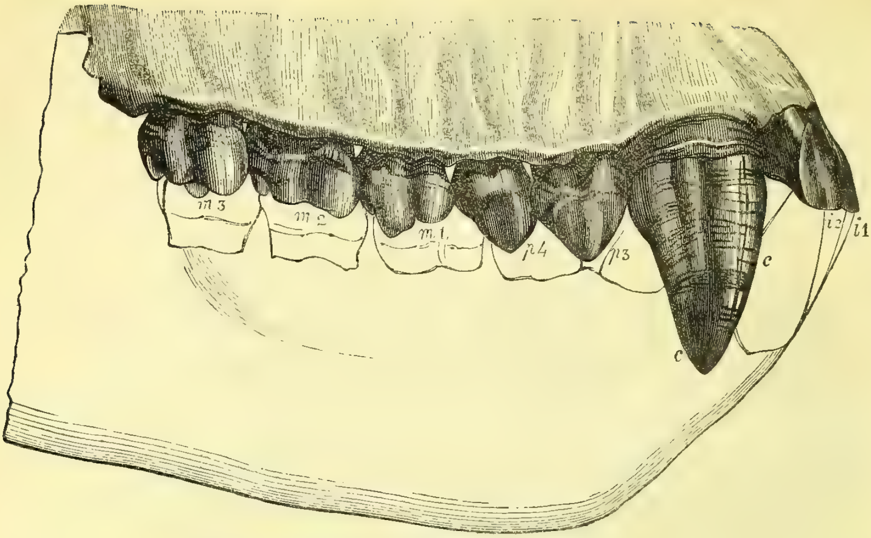
If we were desirous of further testing the soundness of the foregoing conclusions as to the nature of the teeth absent in the reduced dental formula of man, we ought to trace the mode in which the type is progressively resumed in descending from man through the order most nearly allied to our own.

Through a considerable part of the Quadrumanous series, *e. g.* in all the Old World genera above the Lemurs, the same number and kinds of teeth are present as in man; the first deviation being the disproportionate size of the canines and the concomitant break or "diastema" in the dental series for the reception of their crowns when the mouth is shut. This is manifested in both the Chimpanzees and Orangs, together with a sexual difference in the proportions of the canine teeth.

As the precise characteristics of the human dentition are best demonstrated by comparison with that brute species which is most nearly allied to Man, and makes the first step in the descending scale, I here subjoin the details of such a comparison, which is the more required since it is not touched upon in the article QUADRUMANA, and will be the more acceptable as one of its subjects is a species of Chimpanzee (*Troglodytes Gorilla*) *, unknown to science when that article was written, and which, so far as its organisation is known, is more anthropoid than even the docile and smaller species of Chimpanzee (*Troglodytes niger*). A side view of the teeth of a male, full-grown, but not aged, specimen of the great Chimpanzee is given of the natural size in *fig.* 585., and a view of the working surface of the whole series of the upper jaw in *fig.* 586. This dentition, though in all its principal characters strictly quadrumanous, yet, in the

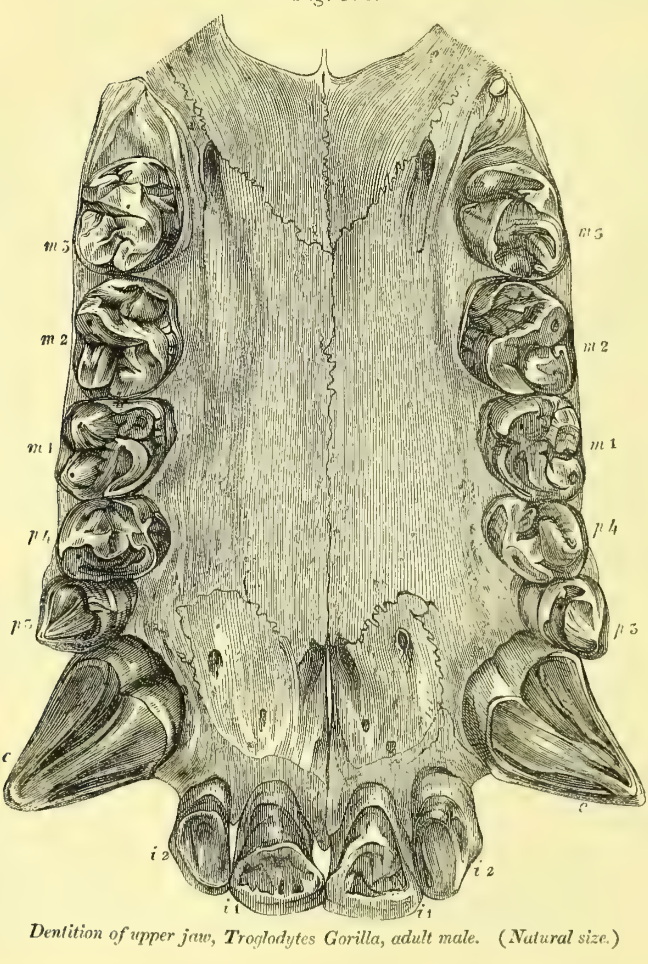
* Drs. Savage and Wyman, Boston Journal of Natural History, 1847; Owen, Transactions of the Zoological Society, vol. iii. p. 381 (February, 1848). M. F. Cuvier has not given a figure of the dentition of any species of Chimpanzee (*Troglodytes*). Believing with his brother, that the Orang (*Pithecus*, Geoffr.) made the nearest approach to man, the dentition of an immature *Pithecus Wurmbii* with one of the characteristically large permanent molars (*m.* 1) in place, immediately follows the plate of the human dentition in the "Dents des Mammifères," 8vo. pls. i. & ii.

Fig. 585.



Dentition of adult male, Troglodytes Gorilla. (Natural size.)

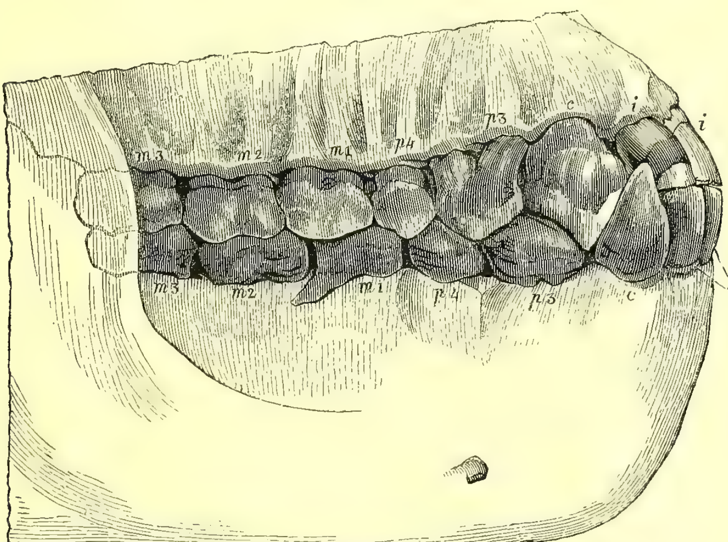
Fig. 586.



Dentition of upper jaw, Troglodytes Gorilla, adult male. (Natural size.)

minor particulars in which it differs from the dentition of the Orang, approaches nearer the human type. In the upper jaw the middle incisors (*fig.* 586, *i.* 1) are smaller, the lateral ones (ib. *i.* 2) larger than those of the Orang*; they are thus more nearly equal to each other; nevertheless the proportional superiority of the middle pair is much greater than in Man, and the proportional size of the four incisors both to the entire skull and to the other teeth is greater. Each incisor has a prominent posterior basal ridge, and the outer angle of the lateral incisors, *i.* 2, is rounded off as in the Orang. The incisors incline forwards from the vertical line as much as in the great Orang. Thus the characteristics of the human incisors are, in addition to their true incisive wedge-like form, their near equality teeth" *, when the mouth is closed, is applicable only to the female, and does not distinguish the Chimpanzees from the Orangs. In the male of the smaller Chimpanzee (*Troglodytes niger*) the upper canine is conical, pointed, but more compressed than in the Orang, and with a sharper posterior edge; convex anteriorly, becoming flatter at the posterior half of the outer surface, and concave on the corresponding part of the inner surface, which is traversed by a shallow longitudinal impression; a feeble longitudinal rising and a second linear impression divide this from the convex anterior surface, which also bears a longitudinal groove at the base of the crown. The canine is rather more than twice the size of that in the female. In the male *Gorilla* (*figs.* 585, 586.), the crown of the canine is

Fig. 587.



Dentition of adult female, Troglodytes Gorilla. (*Natural size.*)

of size, their vertical or nearly vertical position, and small relative size to the other teeth and to the entire skull. The diastema between the incisors and the canine on each side is as well marked in the male Chimpanzee as in the male Orang.† The crown of the canine (ib. *c.*), passing outside the interspace between the lower canine and premolar, extends in the male *Troglodytes Gorilla* a little below the alveolar border of the under jaw when the mouth is shut; the upper canine of the male *Troglodytes niger* likewise projects a little below that border; the seventh character, therefore, which I had formerly assigned to the genus, "apices of canines lodged in intervals of the opposite more inclined outwards: the anterior groove on the inner surface of the crown is deeper; the posterior groove is continued lower down upon the fang, and the ridge between the two grooves is more prominent than in the *Troglodytes niger*. Both premolars (*fig.* 586. *p.* 3 and *p.* 4) are bicuspid; the outer cusp of the first and the inner cusp of the second being the largest, and the first premolar consequently appearing the largest on an external view (*fig.* 585.). The difference is well marked in the female (*fig.* 587, *p.* 3, *p.* 4). The anterior external angle of the first premolar is not produced as in the Orang, which in this respect makes a marked approach to the lower *Quadrumana*. In Man, where the outer curve of the premolar part of the dental series is greater than the inner one, the outer cusps of both premolars are the largest; the alternating superiority of size in the Chimpanzee accords

* Compare *fig.* 586. with pl. xxxii. (*Pithecus Wurmbii*) and pl. xxxiv. (*Pith. Morio*), in vol. ii. Zool. Trans.

† Compare *fig.* 586. with pl. xxxii. (*Pith. Wurmbii*) in vol. ii. Zool. Trans.

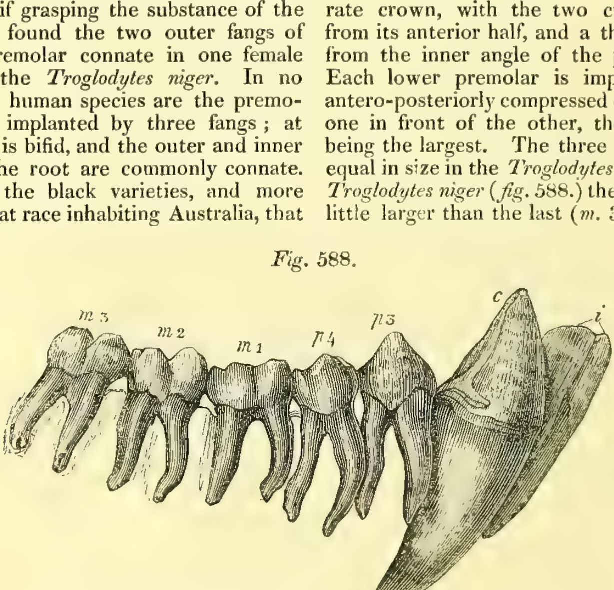
* Zool. Trans. vol. i. p. 372.

with, and contributes to, the straight line which the canine and premolars form with the true molars.

The true molars (*fig.* 586., *m.* 1, *m.* 2, *m.* 3) are quadricuspid, relatively larger in comparison with the bicuspids than in the Orang. In the first and second molars of both species of Chimpanzee a low ridge connects the antero-internal with the postero-external cusp, crossing the crown obliquely, as in Man. There is a feeble indication of the same ridge in the unworn molars of the Orang; but the four principal cusps are much less distinct, and the whole grinding surface is flatter and more wrinkled than in the Chimpanzee. In the *Troglodytes niger* the last molar is the smallest, owing to the inferior development of the two hinder cusps, and the oblique connecting ridge is feebly marked. In the *Troglodytes Gorilla* this ridge is as well developed as in the other molars, but is more transverse in position; and the crown of *m.* 3 is equal in size to that of *m.* 1 or *m.* 2, having the posterior outer cusp, and particularly the posterior inner cusp, more distinctly developed than in the *Troglodytes niger*. The repetition of the strong sigmoid curves which the unworn prominences of the first and second true molars present in Man, is a very significant indication of the near affinity of the Chimpanzee as compared with the approach made by the Orangs or any of the inferior *Quadrumana*, in which the four cusps of the true molars rise distinct and independently of each other. A low ridge girts the base of the antero-internal cusp of each of the upper true molars in the male Chimpanzee: it is less marked in the female. The premolars as well as molars are severally implanted by one internal and two external fangs, diverging but curving towards each other at their ends as if grasping the substance of the jaw. I have found the two outer fangs of the second premolar connate in one female specimen of the *Troglodytes niger*. In no variety of the human species are the premolars normally implanted by three fangs; at most the root is bifid, and the outer and inner divisions of the root are commonly connate. It is only in the black varieties, and more particularly that race inhabiting Australia, that I have found the wisdom tooth, *m.* 3, with three fangs as a general rule; and the two outer ones are more or less confluent.

In the lower jaw of the great Chimpanzee the lateral incisors are broader than the middle ones, although they are smaller relatively than in the *Troglodytes niger;* they are larger and less vertically implanted than in Man. The lower canines are two inches and a half in length, including the root; the enamelled crown is an inch and a quarter in length, and nearly an inch across the base; it is conical and trihedral; the outer and anterior surface is convex, the other two surfaces are flattened or subconcave, and converging to an almost trenchant edge directed inwards and backwards; a ridge separates the convex from the antero-internal flat surface; both this and the posterior surface show slight traces of a longitudinal rising at their middle part. The lower canine of the male shows the same relative superiority of size as the upper one compared with that in the female in both species of Chimpanzee. The canine almost touches the incisor, but is separated by a diastema one line and a half broad from the first premolar. This tooth (*p.* 3) is larger externally than the second premolar, and is three times the size of the human first premolar (*p.* 3); it has a subtrihedral crown, with the anterior and outer angle produced forwards, slightly indicating the peculiar feature of the same tooth in the Baboons, but in a less degree than in the Orang. The summit of the crown of *p.* 3 terminates in two sharp trihedral cusps, the outer one rising highest, and the second cusp being feebly indicated on the ridge extending from the inner side of the first; the crown has, also, a thick ridge at the inner and posterior part of its base. The second premolar (*p.* 4) has a subquadrate crown, with the two cusps developed from its anterior half, and a third smaller one from the inner angle of the posterior ridge. Each lower premolar is implanted by two antero-posteriorly compressed divergent fangs, one in front of the other, the anterior fang being the largest. The three true molars are equal in size in the *Troglodytes Gorilla;* in the *Troglodytes niger* (*fig.* 588.) the first (*m.* 1) is a little larger than the last (*m.* 3), which is the

Fig. 588.



Dental series, lower jaw, adult male, Troglodytes niger. (*Natural Size.*)

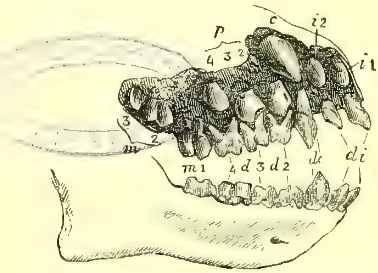
only molar in the smaller Chimpanzee as large as the corresponding tooth in the black varieties of the human subject *, in most of which, especially the Australians, the true molars attain larger dimensions than in the yellow or white races. The four principal cusps, especially the two inner ones, of the first molar of both species of Chimpanzee are more pointed and prolonged than in Man; a fifth small cusp is developed behind the outer pair, as in the Orangs and the Gibbons, but is less than that in Man. The same additional cusp is present in the second molar, which is seldom seen in Man. The crucial groove on the grinding surface is much less distinct than in Man, not being continued across the ridge connecting the anterior pair of cusps in the Chimpanzee. The crown of the third molar is longer antero-posteriorly from the greater development of the fifth posterior cusp, which, however, is rudimental in comparison with that in the Semnopitheques and Macaques. All the three true molars are supported by two distinct and well developed antero-posteriorly compressed divergent fangs, longitudinally excavated on the sides turned towards each other; in the white and yellow races of the human subject these fangs are usually connate in *m.* 3, and sometimes also in *m.* 2. The molar series in both species of Chimpanzee forms a straight line, with a slight tendency in the upper jaw to bend in the opposite direction to the well-marked curve which the same series describes in the human subject.

This difference of arrangement, with the more complex implantation of the premolars, the proportionally larger size of the incisors as compared with the molars; the still greater relative magnitude of the canines; and, above all, the sexual distinction in that respect, illustrated by *figs.* 585. 587., stamp the Chimpanzees most decisively with not merely specific but generic distinctive characters as compared with Man. For the teeth are fashioned in their shape and proportions in the dark recesses of their closed formative alveoli, and do not come into the sphere of operation of external modifying causes until the full size of the crowns has been acquired. The formidable natural weapons, with which the Creator has armed the powerful males of both species of Chimpanzee, form the compensation for the want of that psychical capacity to forge destructive instruments which has been reserved as the exclusive prerogative of Man. Both Chimpanzees and Orangs differ from the human subject in the order of the development of the permanent series of teeth; the second molar (*m.* 2) comes into place before either of the premolars has cut the gum, and the last molar (*m.* 3) is acquired before the canine. We may well suppose that the larger grinders are earlier required by the frugivorous Chimpanzees and Orangs than by the higher organised omnivorous species with more numerous and varied resources, and probably one main condition of the earlier development of the canines and premolars in Man may be their smaller relative size.

* See my Odontography, pl. 119, *fig.* 2, *m.*

In the South American Quadrumana, the number of teeth is increased to thirty-six (art. QUADRUMANA, Vol. IV. p. 210.; *Cebinæ* *), by an addition of one tooth to the molar series on each side of both jaws. It might be concluded, *à priori*, that as three is the typical number of true molars in the placental Mammalia with two sets of teeth, the additional tooth in the *Cebinæ* would be a premolar, and form one step to the resumption of the normal number (four) of that kind of teeth. The proof of the accuracy of this inference is given by the state of the dentition in the young *Cebus* in *fig.* 589., which corresponds with that of the human child in *fig.* 584., *i. e.* the whole of the deciduous dentition is retained, and the first true molar (*m.* 1) is in place on each side of both jaws. The germs of the other teeth of the permanent series are exposed in the upper jaw; and the crown of a premolar is found above the third molar in place, as well as above the second and first. As regards number, therefore, the molar series, in *Cebus*, is intermediate between that of *Mustela* (*fig.* 580., IV.) and *Felis* (ib. V.); the little premolar *p. i.* in *Mustela* tells plainly enough which of the four is wanting to complete the typical number in the South American Monkey, and which is the additional premolar distinguishing its dental formula from that of the Old World monkeys and man. By reference to Prof. Vrolik's article (QUADRUMANA) it will be seen that the eighth genus, including the little Marmoset monkeys (*Hapale*, *Ouistiti*), "have only the same number of teeth as the monkeys of the Old World, viz. 32, $i.\ \frac{4}{4}$, $c.\ \frac{1-1}{1-1}$, $m.\ \frac{5-5}{5-5}$." But the difference is much greater than this numerical conformity would intimate. In a young *Jacchus penicillatus* I find that there are three deciduous molars displaced by three premolars, as in the other South American Quadrumana, and that it is the last true molar, *m.* 3, the development of which is suppressed, not the premolar *p.* 2, and thus these diminutive squirrel-like monkeys actually differ

Fig. 589.



Deciduous and permanent teeth of Cebus.

* The dental series seems, unluckily, not to have been complete in either of the skulls represented by the distinguished author of that able article (*figs.* 132, 133).

from the Old World Quadrumana more than the *Cebidæ* do; *i.e.* they differ not only in having four teeth ($p.\ 2\ \frac{1-1}{1-1}$), which the monkeys of the Old World do not possess, but also by wanting four teeth ($m.\ 3\ \frac{1-1}{1-1}$), which those monkeys, as well as the *Cebidæ*, actually have. It is thus that the investigation of the exact homologies of parts leads to a recognition of the true characters indicative of zoological affinity.

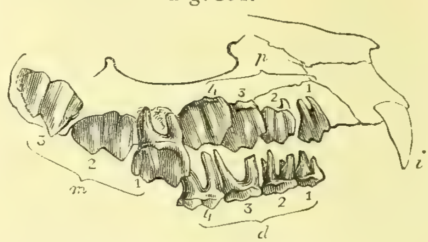
Most of the *Lemurinæ* have $p.\ \frac{3-3}{3-3}$, $m.\ \frac{3-3}{3-3}$, together with remarkable modifications of their incisive and canine teeth, of which an extreme example is shown in the pectinated tooth (*fig.* 556.) of the *Galeopithecus*. The inferior incisors slope forwards in all, and the canines also, which are contiguous to them, and very similar in shape. In the *Chirogaleus* these canines are entered as incisors in the dental formula of the genus (Vol. IV. p. 215), and the laniariform premolar (*p.* 2) is entered as a canine: M. Vrolik also describes four teeth on each side of the upper jaw, and four on each side of the lower jaw, as true tuberculated molars. They have tuberculated crowns, but the value of shape as a character is too small to permit our accepting so great an anomaly without the requisite proof of their order of development and succession.

Even in the hoofed quadrupeds with toes in uneven number (*Perissodactyla*), whose premolars, for the most part, repeat both the form and the complex structure of the true molars, such premolars are distinguished by the same character of development as those of the *Artiodactyla*, or Ungulates with toes in even number; although in these the premolars are distinguished also by modifications of size and shape. The complex ridged and tuberculate crowns of the second, third, and fourth grinders of the Rhinoceros, Hyrax (*fig.* 590.), and horse, no more prove them to be true molars, than the trenchant shape of the lower carnassials of the lion proves them to be false molars. It is by development alone that the primary division of the series of grinding teeth can be established, and by that character only can the homologies of each individual tooth be determined, and its proper symbol applied to it.

In pl. 136, *fig.* 5, of my Odontography, the three posterior teeth of the almost uniform grinding series of the horse's dentition are thus proved to be the only ones entitled to the name of "true molars;" and, if any one should doubt the certainty of the rule of counting, by which the symbols, *p.* 4, *p.* 3, and *p.* 2, are applied to the three large anterior grinding teeth (ib. *fig.* 19), which are commonly the only premolars present in each lateral series of the horse's jaws, yet the occasional retention of the diminutive tooth, *p.* 1 (ib. *fig.* 6), would establish its accuracy, whether such tooth be regarded as the first of the deciduous series unusually long retained, or the unusually small and speedily lost successor (*p.* 1) of an abortive *d* 1.

The law of development, so beautiful for its instructiveness and constancy in the placental *Diphyodonts*, is here illustrated in the little *Hyrax* (*fig.* 591.), in which the *d.* 1 is

Fig. 591.

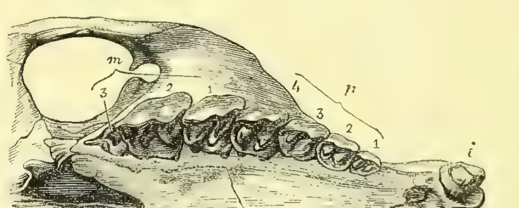


Deciduous and permanent molars of the Hyrax.

normally developed and succeeded by a permanent *p.* 1, differing from the rest only by a graduated inferiority of size, which, in regard to the last premolar, ceases to be a distinction between it and the first true molar.

The elephant, which by its digital characters belongs to the odd-toed, or perissodactyle, group of Pachyderms, also resembles them in the close agreement in form and structure of the grinding teeth representing the premolars, with those that answer to the true molars of the Hyrax, Tapir, and Rhinoceros. The gigantic Proboscidian Pachyderms of Asia and Africa present, however, so many peculiarities of structure, as to have led to their being located in a particular family in the Systematic Mammalogies. And this seems to be justified

Fig. 590.



Molar series, upper jaw (Hyrax).

by no character more than by the singular seeming exception which they present to the Diphyodont rule which governs the dentition of other hoofed quadrupeds. In fact, the elephant, like the Dugong, sheds and replaces vertically only its incisors, which are also two in number, very long, and of constant growth, forming tusks, with an analogous sexual difference in this respect in the female of the Asiatic species. The molars, also, are successively lost, are not vertically replaced, and are reduced finally to one on each side of both jaws, which is larger than any of its predecessors. These analogies are interesting and suggestive in connection with the other approximations in the "Sirenia" to the pachydermal type, which I have pointed out in the "Proceedings of the Zoological Society."*

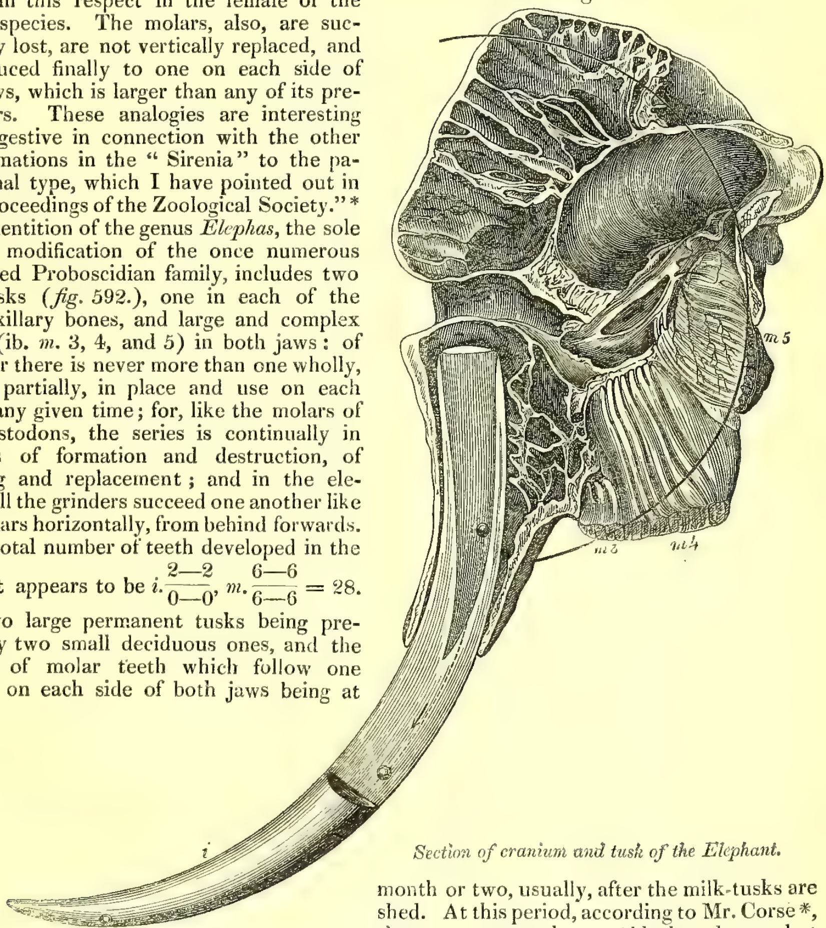
The dentition of the genus *Elephas*, the sole existing modification of the once numerous and varied Proboscidian family, includes two long tusks (*fig.* 592.), one in each of the Intermaxillary bones, and large and complex molars (ib. *m.* 3, 4, and 5) in both jaws: of the latter there is never more than one wholly, or two partially, in place and use on each side at any given time; for, like the molars of the Mastodons, the series is continually in progress of formation and destruction, of shedding and replacement; and in the elephants all the grinders succeed one another like true molars horizontally, from behind forwards.

The total number of teeth developed in the elephant appears to be $i.\frac{2-2}{0-0}, m.\frac{6-6}{6-6} = 28$. The two large permanent tusks being preceded by two small deciduous ones, and the number of molar teeth which follow one another on each side of both jaws being at least six, of which the last three may, by analogy, be regarded as answering to the true molars of other Pachyderms. I have shown in my Odontography that: —

"The deciduous tusk makes its appearance beyond the gum between the fifth and seventh month; it rarely exceeds two inches in length, and is about a third of an inch in diameter at its thickest part, where it protrudes from the socket; the fang is solidified, and contracts to its termination, which is commonly a little bent, and is considerably absorbed by the time the tooth is shed, which takes place between the first and second year.†

"The socket of the permanent tusk in a new-born elephant, is a round cell about three lines in diameter, situated on the inner and posterior side of the aperture of the temporary socket. The permanent tusks cut the gum when about an inch in length, a

Fig. 592.



Section of cranium and tusk of the Elephant.

month or two, usually, after the milk-tusks are shed. At this period, according to Mr. Corse*, the permanent tusks are 'black and ragged at the ends. When they become longer, and project beyond the lip, they soon are worn smooth by the motion and friction of the trunk.' Their widely open base is fixed upon a conical pulp, which, with the capsule surrounding the base of the tusk and the socket, continues to increase in size and depth, obliterating all vestiges of that of the deciduous tusk, and finally extending its base close to the nasal aperture (*fig.* 592.). The tusk is formed by successive calcification of layers of the pulp in contact with the inner surface of the pulp cavity; and, being subject to no habitual attrition from an opposed tooth, but being worn only by the occasional uses to which it is applied, it arrives at an extraordinary length, following the curve originally

* 1838, p. 40.

† See Mr. Corse's "Memoir on the Teeth of the Elephant," in Philosophical Transactions, 1799, p. 211: a good figure of the deciduous tusk is given in plate 5.

* Loc. cit., p. 212.

impressed upon it by the form of the socket, and gradually widening from the projecting apex to that part which was formed when the matrix and the socket had reached their full size.

"These incisive teeth of the elephant not only surpass other teeth in size, as belonging to a quadruped so enormous, but they are the largest of all teeth in proportion to the size of the body; representing in a natural state those monstrous incisors of the Rodents, which are the result of accidental suppression of the wearing force of the opposite teeth."

The tusks of the elephant, like those of the Mastodon, consist chiefly of that modification of dentine which is called "ivory," and which shows, on transverse fractures or sections, striæ proceeding in the arc of a circle from the centre to the circumference, in opposite directions, and forming by their decussations curvilinear lozenges. This character is peculiar to the Proboscidian Pachyderms.

In the Indian elephant the tusks are always short and straight in the female, and less deeply implanted than in the male: she thus retaining, as usual, more of the characters of the immature state. In the male they have been known to acquire a length of nine feet, with a basal diameter of eight inches, and to weigh one hundred and fifty pounds; but these dimensions are rare in the Asiatic species.

Mr. Corse, speaking of the variety of Indian elephant, called "Dauntelah" from its large tusks, which project almost horizontally with a slight curve upwards and outwards, says, "The largest I have known in Bengal did not exceed seventy-two pounds avoirdupois; at Tiperah they seldom exceed fifty pounds." There are varieties of the Dauntelah in which the large tusks of the male are nearly or quite straight; and in a more marked breed called "Mooknah," the tusks are much smaller, are straight, and point directly downwards. These ascertained varieties in an existing species ought to weigh with the observers of analogous varieties in the teeth of fossil Proboscidians, before they pronounce definitely on their value as characters of distinct species. More anomalous varieties occasionally present themselves in the Indian Elephant, as when one tusk is horizontal, the other vertical; or when, from some distortion of the alveolus, a spiral direction is impressed upon the growth of the tusk, as in that specimen figured by Grew in the "Rarities of Gresham College," Tab. 4., and which is now in the Museum of the Royal College of Surgeons, London. The tusk of the elephant is slightly moveable in its socket, and readily receives a new direction of growth from habitual pressure; this often causes distorted tusks in captive elephants, and Cuvier * relates the mode in which advantage was taken of the same impressibility, in order to rectify the growth of such tusks in an elephant kept at the Garden of Plants.

The tusks of the extinct *Elephas primigenius*, or Mammoth, have a bolder and more extensive curvature than those of the *Elephas indicus:* some have been found which describe a circle; but, the curve being oblique, they thus clear the head, and point outwards, downwards, and backwards. The numerous fossil tusks of the Mammoth which have been discovered and recorded, may be ranged under two averages of size: the larger ones at nine feet and a half, the smaller at five feet and a half in length. I have elsewhere * assigned reasons for the probability of the latter belonging to the female Mammoth, which must accordingly have differed from the existing elephant of India, and more resembles that of Africa in the development of her tusks; yet manifesting an intermediate character by their smaller size. Of the tusks which are referable to the male Mammoth, one from the newer tertiary deposits in Essex, measured nine feet ten inches along the outer curve, and two feet five inches in circumference at its thickest part; another from Eschscholtz Bay was nine feet two inches in length, and two feet one and a half inches in circumference, and weighed one hundred and sixty pounds. A Mammoth's tusk has been dredged up off Dungeness which measured eleven feet in length. In several of the instances of Mammoth's tusks from British strata, the ivory has been so little altered as to be fit for the purposes of manufacture; and the tusks of the Mammoth, which are still better preserved in the frozen drift of Siberia, have long been collected in great numbers as articles of commerce.†

Cuvier ‡ states that the elephant of Africa, at least in certain localities, has large tusks in both sexes, and that the female of this species, which lived seventeen years in the menagerie of Louis XIV., had larger tusks than those in any Indian elephant, male or female, of the same size which he had seen. The ivory of the tusks of the African elephant is most esteemed by the manufacturer for its density and whiteness.

The molar teeth of the elephant are remarkable for their great size, even in relation to the bulk of the animal, and for the extreme complexity of their structure. The crown, of which a great proportion is buried in the socket, and very little more than the grinding surface appears above the gum, is deeply divided into a number of transverse perpendicular plates (*fig.* 557), consisting each of a body of dentine (*d*), coated by a layer of enamel (*e*), and this again by the less dense bone-like

* Ossemens Fossiles, 4to. 1821, tom. i. p. 47.

* History of British Fossil Mammalia, 8vo. 1844, p. 244.

† In the account of the Mammoth's bones and teeth of Siberia, published in the "Philosophical Transactions" for 1737 (No. 446), tusks are cited which weighed two hundred pounds each, and "are used as ivory, to make combs, boxes, and such other things; being but little more brittle, and easily turning yellow by weather and heat." From that time to the present there has been no intermission in the supply of ivory, furnished by the tusks of the extinct elephants of a former world.

‡ Loc. cit., p. 55.

substance (c) which fills the interspaces of the enamelled plates, and here more especially merits the name of "cement," since it binds together the several divisions of the crown before they are fully formed and united by the confluence of their bases into a common body of dentine. As the calcification of each plate begins at the summit, they remain detached from each other and like so many separate teeth or denticules, until their base is completed, when it becomes blended with the bases of contiguous plates to form the common body of the crown of the complex tooth from which the roots are next developed.

The plates of the molar teeth of the Siberian Mammoth (*Elephas primigenius*) are thinner in proportion to their breadth, and are generally a little expanded at the middle; and they are more numerous in proportion to the size of the crown than in the existing species of Asiatic Elephant. In the African Elephant, on the other hand, the lamellar divisions of the crown are fewer and thicker, and they expand more uniformly from the margins to the centre, yielding a lozenge-form when cut or worn transversely, as in mastication.

The horizontal as well as vertical course of development of the elephant's grinder is well illustrated by the Mammoth's molar, the last of the lower jaw. The separate digital processes of the posterior plates are still distinct, and adhere only by the remaining cement; a little in advance we see them united to form the transverse plate; and, at the opposite extremity of the tooth, the common base of dentine is exposed by which the plates are finally blended into one individual complex grinder*; this never takes place simultaneously along the whole course of the tooth in the larger molars of the existing Indian elephant, or its extinct congener, the Mammoth. The African elephant, and some of the extinct Indian species, as the *El. planifrons*, manifest their affinity to the Mastodon by the basal confluence of the hindmost plates before the foremost ones are worn out. The formation of each grinder begins with the summits of the anterior plate, and the rest are completed in succession; the tooth is gradually advanced in position as its growth proceeds; and, in the existing Indian elephant, the anterior plates are brought into use before the posterior ones are formed. When the complex molar cuts the gum the cement is first rubbed off the digital summits: then their enamel cap is worn away, and the central dentine comes into play with a prominent enamel ring; the digital processes are next ground down to their common uniting base, and a transverse tract of dentine with its wavy border of enamel is exposed; finally, the transverse plates themselves are abraded to their common base of dentine, and a smooth and polished tract of that substance is produced.* From this basis the roots of the molar are developed, and increase in length to keep the worn crown on the grinding level, until the reproductive force is exhausted. When the whole extent of a grinder has successively come into play, its last part is reduced to a long fang supporting a smooth and polished field of dentine, with, perhaps, a few remnants of the bottom of the enamel folds at its hinder part. When the complex molar has been thus worn down to a uniform surface it becomes useless as an instrument for grinding the coarse vegetable substances on which the elephant subsists; it is attacked by the absorbent action, and the wasted portion of the molar is finally shed.

The grinding teeth of the elephant progressively increase in size, and in the number of lamellar divisions, from the first to the last; and, as the rate of increase in both respects is nearly identical in both jaws, I shall describe them chiefly as they appear in the lower one.

The *first molar*, which cuts the gum in the course of the second week after birth, has a sub-compressed crown, nine lines in antero-posterior diameter, divided by three transverse clefts into four plates, the third being the broadest, and the tooth here measuring six lines across †; the first and second plates have two mammilloid summits; the third and fourth have three or four such; there is a single and sometimes a double mammilloid summit at the fore and back part of the crown: the base slightly contracts, and forms a neck as long as the enamelled crown, but of less breadth, and this divides into two, an anterior and posterior, long, sub-cylindrical, diverging, but mutually incurved fangs; the total length of this tooth is one inch and a half. The corresponding upper molar, which Mr. Corse describes as cutting the gum a little earlier than the lower one, has the anterior single digital process or mammilla, and the posterior talon developed into a fifth plate, smaller than the fourth, with which its middle part is confluent; the neck of this tooth is shorter, and the two fangs are shorter, larger, and more compressed than those of the lower first molar. This tooth is the homologue of the probably deciduous molar (d. 2) in other

* Some anatomists describe the divisions of the crown of the elephant's grinder as so many "distinct teeth;" and Mr. Corse (loc. cit. p. 213.), who first propounded this view, calls each complex grinder "a case of teeth," and states "that these teeth are merely joined to each other by an intermediate softer substance, acting like a cement." But this description applies only to the imperfectly-formed tooth; and the detached eminences of the crown of any complex tooth, at that stage of growth when they are held together only by the still uncalcified supporting matrix, might with equal justice be regarded as so many distinct teeth.

* In the fossil specimen figured in plate 147, of my "Odontography," the left molar l, exhibits all the above-described gradations of use; but the right molar, r, through some accident to the opposing tooth in the lower jaw, has not been so worn, but projects beyond the level of the left molar, with the mammillated margins of the plates entire.

† These are also the dimensions of the first lower molar figured by Mr. Corse, loc. cit. pl. vi. *fig.* 1, D, and *fig.* 3; but I have seen the first lower molar of smaller dimensions.

Ungulates; it is not a mere miniature of the great molars of the mature animal, but retains, agreeably with the period of life at which it is developed, a character much more nearly approaching that of the ordinary Pachydermal molar, manifesting the adherence to the more general type by the minor complexity of the crown, and by the form and relative size of the fangs. In the transverse divisions of the crown we perceive the affinity to the Tapiroid type, the different links connecting which with the typical elephants are supplied by the extinct Lophiodons, Dinotheriums, and Mastodons. The sub-division of the summits of the primary plates recalls the character of the molars, especially the smaller ones, of the Phacochere in the Hog-tribe. As the elephant advances in age the molars rapidly acquire their more special and complex character.

The first molars are completely in place, and in full use at three months, and are shed when the elephant is about two years old.

The sudden increase and rapid development of the *second molar* may account for the non-existence of any vertical successor to the former tooth, or "premolar," in the elephant. The eight or nine plates of the crown are formed in the closed alveolus, behind the first molar by the time this cuts the gum, and they are united with the body of the tooth, and most of them in use, when the first molar is shed.

The average length of the second molar is two inches and a half; ranging from two inches to two inches and nine lines. The greatest breadth, which is behind the middle of the tooth, is from one inch to one inch three lines. There are two roots: the cavity of the small anterior one expands in the crown, and is continued into that of the three anterior plates. The thicker root supports the rest of the tooth. The second molar is worn out and shed before the beginning of the sixth year.

The *third molar* has the crown divided into from eleven to thirteen plates; it averages four inches in length, and two inches in breadth, and has a small anterior, and a very large posterior root; it begins to appear above the gum about the end of the second year, is in its most complete state and extensive use during the fifth year, and is worn out and shed in the ninth year. The last remnant of the third molar is shown at *m.* 3, *fig.* 592.

It is probable that the three teeth above described are homologous with the deciduous molars, *d.* 2, *d.* 3, and *d.* 4, in the Hyrax and horse.

The *fourth molar* presents a marked superiority of size over the third, and a somewhat different form: the anterior angle is more obliquely abraded, giving a pentagonal figure to the tooth in the upper jaw (*fig.* 592. *m.* 4). The number of plates in the crown of this tooth is fifteen or sixteen: its length between seven and eight inches; its breadth three inches. It has an anterior simple and slender root supporting the three first plates; a second of larger size and bifid, supporting the four next plates; and a large contracting base for the remainder. The fore-part of the grinding surface of this tooth begins to protrude through the gum at the sixth year: the tooth is worn away, and its last remnant shed, about the twentieth or twenty-fifth year. It may be regarded as the homologue of the first true molar of ordinary Pachyderms (*m.* 1).

The *fifth molar*, with a crown of from seventeen to twenty plates, measures between nine and ten inches in length, and about three inches and a half in breadth. The second root is more distinctly separated from the first simple root than from the large mass behind. It begins to appear above the gum about the twentieth year: its duration has not been ascertained by observation; but it probably is not shed before the sixtieth year.

The *sixth molar* appears to be the last, and has from twenty-two to twenty-seven plates; its length, or antero-posterior extent, following the curvature, is from twelve to fifteen inches: the breadth of the grinding surface rarely exceeds three inches and a half.

The reproductive power of the matrix in some cases surpasses that of the formative development of the cavity for lodging the tooth, and the last lamellæ are obliged to be folded from behind forwards upon the side of the tooth. *Fig.* 99, p. 233. of my "History of British Fossil Mammals," shows this condition in the last lower molar of the Mammoth.

One may reasonably conjecture that the sixth molar of the Indian elephant, if it make its appearance about the fiftieth year, would, from its superior depth and length, continue to do the work of mastication until the ponderous Pachyderm had passed the century of its existence.

Mr. Corse has figured the sixth molar, (which he calls the seventh or eighth,) with twenty-three plates, in tab. x. of his Memoir, and a small cavity, c, is marked as an incipient alveolus for a succeeding grinder. Had it actually been such, it might have been expected to contain some calcified portions of the anterior plates of such succeeding grinder.

The molar teeth, in all the species of elephant, succeed each other from behind forwards, moving, not in a right line, but in the arc of a circle, shown by the curved line in *fig.* 592. The position of the growing tooth in the closed alveolus (*m.* 5) is almost at right angles with that in use, the grinding surface being at first directed backwards in the upper jaw, and forwards in the lower jaw, and brought, by the revolving course, into a horizontal line in both jaws, so that they oppose each other, when developed for use. The imaginary pivot on which the grinders revolve is next their root in the upper jaw, and is next the grinding surface in the lower jaw; in both, towards the frontal surface of the skull. Viewing both upper and lower molars as one complex whole, subject to the same revolving movement, the section dividing such whole into upper and lower portion runs parallel to the curve described by that movement, the upper being the central portion, or that nearest the pivot, the lower, the peripheral portion: the grinding surface of the upper molars is consequently convex from behind forwards, and that of the lower molars concave: the upper molars are always broader than the lower ones. The bony plate forming the sockets of the growing teeth is more than usually distinct from the body of the maxillary, and participates in this revolving course, advancing forwards with the teeth. The partition between the tooth in use and its successor is perforated near the middle; and, in its progress forwards, that part next the grinding surface is first absorbed; the rest disappearing with the absorption of the roots of the preceding grinder.

There are few examples of organs that manifest a more striking adaptation of a highly complex and beautiful structure to the exigencies of the animal endowed with it, than the grinding teeth of the elephant. We perceive, for example, that the jaw is not encumbered with the whole weight of the massive tooth at once, but that it is formed by degrees as it is required; the division of the crown into a number of successive plates, and the subdivision of these into cylindrical processes, presenting the conditions most favourable to progressive formation. But a more important advantage is gained by this subdivision of the tooth; each part is formed like a perfect simple tooth, having a body of dentine, a coat of enamel, and an outer investment of cement: a single digital process may be compared to the simple canine of a Carnivore; a transverse row of these, therefore, when the work of mastication has commenced, presents, by virtue of the different densities of their constituent substances, a series of cylindrical ridges of enamel, with as many depressions of dentine, and deeper external valleys of cement: the more advanced and more abraded part of the crown is traversed by the transverse ridges of the enamel inclosing the depressed surface of the dentine, and separated by the deeper channels of the cement: the fore-part of the tooth exhibits its least efficient condition for mastication; the inequalities of the grinding surface being reduced in proportion as the enamel and cement which invested the dentinal plates have been worn away. This part of the tooth is, however, still fitted for the first coarse crushing of the branches of a tree: the transverse enamel ridges of the succeeding part of the tooth divide it into smaller fragments, and the posterior islands and tubercles of enamel pound it to the pulp fit for deglutition. The structure and progressive development of the tooth not only give to the elephant's grinder the advantage of the uneven surface which adapts the millstone for its office, but, at the same time, secure the constant presence of the most efficient arrangement for the finer comminution of the food, at the part of the mouth which is nearest the fauces.

With regard to the *microscopic structure* of the peculiar modification of dentine called "ivory," this is characterised partly by the minute size of the tubes, which, at their origin from the pulp cavity, do not exceed $\frac{1}{15000}$th of an inch in diameter, in their close arrangement at intervals scarcely exceeding the breadth of a single tube, and, above all, on their strong and almost angular gyrations, which are much greater than the secondary curvatures of the tubes of ordinary dentine.

The dentinal tubes of ivory, as they radiate from the pulp-cavity, incline obliquely towards the pointed end of the tusk, and describe two slight primary curves, the first convex towards that end, the second and shorter one concave; these curves in narrow sections from near the open base of the tusk are almost obscured by the strong angular parallel secondary gyrations. The tubes divide dichotomously, at acute angles, and gradually decrease in size as they approach the periphery of the tusk.

The characteristic appearance of decussating curved striæ, with oblique rhomboidal spaces, so conspicuous on transverse sections or fractures of ivory, is due to the refraction of light caused by the parallel secondary gyrations of the tubes above described. The strong contour lines observed in longitudinal sections of ivory, parallel with the cone of the pulp-cavity, and which are circular and concentric when viewed in transverse slices of the tusk, are commonly caused by strata of minute opaque cellules, which are unusually numerous in the interspaces of the tubes throughout the substance of the ivory, and by their very great abundance and larger size in the peripheral layers of cement. The close-set lateral branches of the calcigerous tubes unite with the tubuli of the cells. The decomposition of the fossil tusks into superimposed conical layers takes place along the strata of the opaque cellules, and directly across the course of the calcigerous gyrating tubes.

The radiated cells of the true cement are larger and more uniform in size and shape; many of them approach nearer the circular figure than in ordinary teeth; the long axis of the more elliptical ones is parallel with the plane of the stratum of cement; their average diameter is $\frac{1}{2500}$th of an inch, and their interspaces sometimes do not exceed that dimension. The cemental tubuli appear from their course, and sometimes from the overlapping of the substances in the sections examined, to be directly continued from the tubuli of the ivory; but Retzius expressly denies the continuation, and states that the cemental tubes at both the outer and the inner surface of the cement have terminations of less diameter than their middle part. This is exact with respect to the major part of the cement. In that near the base of the tusk I have seen a few vascular canals. The contour lines of the cement are usually wavy, and not parallel with the line of the outer surface of the ivory.

In the tusks of the *Mastodon giganteus* the outer layer of cement is relatively thicker than in the tusks of the Mammoth or in those of the Indian elephant. The general character of the microscopic structure of the ivory of the Mastodon's tusk is the same as that of the elephant. The peripheral extremities of the dentinal tubes are, in some parts of the tusk, straighter than in the rest of their course; the straighter extremities were those which were first formed in the calcification of the peripheral part of the pulp, and this first-formed ivory is accordingly, in such parts, more like the ordinary dentine, and is analogous to the thin peripheral cap of such substance in the teeth of the Sloth and of some fishes.

The pulp soon, however, becomes subject to that modification of the calcifying processes by which the more tortuous disposition of the tubuli and the more frequent interposition of opaque cellules are produced; modifications which, in establishing the characters of ivory, present a step in the transition from true dentine to osteo-dentine.

By the minuteness and close arrangement of the tubes, and especially by their strongly undulating secondary curves, a tougher and more elastic tissue is produced than results from their disposition in ordinary dentine; and the modification which distinguishes "ivory" is doubtless essential to the due degree of coherence of so large a mass as the elephant's tusk, projecting so far from the supporting socket, and to be frequently applied in dealing hard blows and thrusts.

The central part of the tusk, especially near the base of such as have reached their full size, is occupied by a slender cylindrical tract of modified ivory, perforated by a few vascular canals, which is continued to the apex of the tusk. It is not uncommon to find processes of osteo-dentine or imperfect bone-like ivory, projecting in a stalactitic form * into the interior of the pulp-cavity, apparently the consequence of partial inflammation or malformation of the vascular pulp. The musket-balls and other foreign bodies which are occasionally found in ivory, are immediately surrounded by osteo-dentine in greater or less quantity. It has long ceased to be a matter of wonder how such bodies should become completely imbedded in the substance of the tusk, sometimes without any visible aperture, or how a leaden bullet may have become lodged in the solid centre of a very large tusk without having been flattened. Such a ball, aimed at the head of an elephant, may penetrate the thin bony socket and the thinner ivory parietes of the wide conical pulp-cavity occupying the inserted base of the tusk; if the projectile force was there spent, the ball would gravitate to the opposite and lower side of the pulp-cavity, as indicated in *fig.* 592.† The presence of the foreign body exciting inflammation of the pulp, an irregular course of calcification ensues, which results in the disposition around the ball of a certain thickness of osteo-dentine. The pulp then resuming its healthy state and functions, coats the inner surface of the osteo-dentine inclosing the ball, together with the rest of the conical cavity into which that mass projects, with layers of normal ivory.*

The portion of the cement-forming capsule surrounding the base of the tusk, and the part of the pulp, which were perforated by the ball in its passage, are soon replaced by the active reparative power of these highly vascular bodies. The hole formed by the ball in the base of the tusk is then more or less completely filled up by a thick coat of cement from without and of osteo-dentine from within. Traces of such a cicatrix closing the entrance have been more than once noticed: and Blumenbach deduced, therefrom, a property in the elephant's tusk to pour out bony matter in order to heal such wounds. The reparation is however effected by the calcification of the reproduced parts of the capsule and pulp.

By the continued progress of growth, the ball so inclosed is carried forwards, in the course indicated by the arrow in *fig.* 592., to the middle of the solidified exserted part of the tusk, as in the example in Blumenbach's collection which he considered so curious. Should the ball have penetrated the base of the tusk of a young elephant, it may be carried forwards by the uninterrupted growth of the tusk until that base has become the apex, and be finally exposed and discharged by the continual abrasion to which the apex of the tusk is subjected. Yet none of these phenomena prove the absolute non-vascularity of the tusk, but only the low degree of its vascularity. Blood circulates, slowly no doubt, through the minute vascular canals which are continued through the centre of the ivory to the very apex of the tusk: and it is from this source that the fine tubular structure of the ivory obtains the plasmatic colourless fluid by which its low vitality is maintained.

Development.—The matrix of the tusk consists of a large conical pulp, which is renewed quicker than it is converted, and thus is not only preserved, but grows, up to a certain period of the animal's life: it is lodged in the cavity at the base of the tusk; this base is surrounded by the remains of the capsule, a soft vascular membrane of moderate thickness, which is confluent with the border of the base of the pulp, where it receives its principal vessels.

* Haller seems to have been the first to notice these irregular internal deposits in the pulp-cavity of the elephant's tusk. Elementa Physiologiæ, tom. viii. p. 519.

† Camper, "Description Anatomique d'un Eléphant Male," fol. p. 54. Cuvier, Annales du Muséum, tom. viii. (1806) p. 115.

* Cuvier, "Annales du Muséum," tom. viii. p. 115, 1806, "Sur les défenses des éléphans, la structure, l'accroissement, les caractères distinctifs de l'ivoire, et sur les maladies," first clearly stated that the ball or foreign body in the tusk of the elephant was immediately surrounded by a substance different from the regular ivory. The great anatomist observes, "Toute la portion d'ivoire en dehors de la balle est semblable au reste; il n'y a que ce qui l'entoure immédiatement qui soit irrégulier."

I had the tusk and pulp of the great elephant at the Zoological Gardens longitudinally divided, soon after the death of that animal in the summer of 1847. Although the pulp could be easily detached from the inner surface of the pulp-cavity, it was not without a certain resistance, and when the edges of the co-adapted pulp and tooth were examined by a strong lens, the filamentary processes from the outer surface of the pulp could be seen stretching, as they were withdrawn from the dentinal tubes, before they broke. They are so minute that, to the naked eye, the detached surface of the pulp seems to be entire, and Cuvier was thus deceived in concluding that there was no organic connection between the pulp and the ivory.* As the learned professor who has contributed the article "PACHYDERMATA" adopts Cuvier's description of the formation of the teeth of the elephant by deposition and transudation of the tissues from free surfaces of the formative organs, I have the more valued the rare opportunity of testing and confirming, by examination of the recent animal, the account of the processes of conversion of those organs into the dental tissues, which I gave in my "Odontography."

Each molar of the elephant is formed in the interior of a membranous sac—the capsule, the form of which partakes of that of the future tooth, being cubical in the first molar, oblong in the last, and rhomboidal in most of the intermediate teeth; but always decreasing in vertical extent towards its posterior end, and closed at all points, save where it is penetrated by vessels and nerves. It is lodged in an osseous cavity of the same form as itself, and usually in part suspended freely in the maxillary bone; the bony case being destined to form part of the socket of the tooth. The exterior of the membranous capsule is simple and vascular, as shown at *m*. 5, *fig*. 592.; its internal surface gives attachment to numerous folds or processes, as in most other Ungulate animals.

The dentinal pulp rises from the bottom of the capsule, or that part which lines the deepest part of the alveolus, in the form of transverse parallel plates extending towards that part of the capsule ready to escape from the socket. These plates adhere only to the bottom of the capsule; their opposite extremity is free from all adhesion. This summit is thinner than the base; it might be termed the edge of the plate: but it is notched, or divided into many digital processes. The tissue of these digitated plates is identical with that of the dentinal pulp of simple Mammalian teeth; it becomes also highly vascular at the parts where the formation of the dentine is in active progress.

Processes of the capsule descend from its summit into the interspaces of the dentinal pulp-plates, and consequently resemble them in form; but they adhere not only by their base to the surface of the capsule next the mouth, but also by their lateral margins to the sides of the capsule, and thus resemble partition-walls, confining each plate of the dentinal pulp to its proper chamber; the margin of the partition opposite its attached base is free in the interspace of the origins of the dentinal pulp plates. The enamel organ, which Cuvier appears to have recognised under the name of the internal layer of the capsule, is distinguishable by its light blue sub-transparent colour and usual microscopic texture, adhering to the free surface of the partitions formed by the true inner layer of the capsule. Although the enamel-pulp be in close contact with the dentinal pulp prior to the commencement of the formation of the tooth, one may readily conceive a vacuity between them, which is continued uninterruptedly, in many foldings, between all the gelatinous plates of the dentinal pulp, and the partitions formed by the combined enamel-pulp and the folds of the capsule. According to the excretion-view, this delicate apparatus must have been immediately subjected to the violence of being compressed in the unyielding bony box, by the deposition of the dense matters of the tooth in the hypothetical vacuity between the enamel and dentinal pulps; a process of absorption must have been conceived to be set on foot immediately that the altered condition of the gelatinous secreting organs took place; and, according to Cuvier's hypothesis, the secreting function must be supposed to have proceeded, without any irregularity or interruption, while the process of absorption was superinduced in the same part to relieve it from the effects of pressure produced by its own secretion.

The formation of the dentine commences immediately beneath the *membrana propria* of the pulp: a part which Cuvier distinctly recognised, and which he accurately traced as preserving its relative situation between the dentine and enamel throughout the whole formation of the dentine, and discernible in the completed tooth "as a very fine greyish line, which separates the enamel from the internal substance" or dentine.

The calcification and conversion of the cells of the dentinal pulp commence as usual at the peripheral parts of the lamelliform processes furthest from the attached base. It may readily be conceived, therefore, that, at the commencement, there is formed a little cap upon each of the processes into which the edges of the pulp-plates are divided. As the centripetal calcification proceeds the caps are converted into horn-shaped cones; when it has reached the bottom of the notches of the edge of the pulp-plate all the cones become united together into a single transverse plate; and, the process of conversion having reached the base of the pulp-plate, these plates coalesce to form a common base to the crown of the tooth, which would then present the same eminences and notches that characterised the gelatinous pulp, if, during the period of conversion, other substances had

* Annales du Muséum, tom. viii. (1806), p. 94. The account is repeated verbatim in the posthumous edition of the "Ossemens Fossiles," 1836.

not been formed upon the surface and in the interspaces of the pulp-plates.

Coincident, however, with the formation of the dentine, is the deposition of the hardening salts of the enamel in the extremely slender prismatic cells, which are for the most part vertical to the plane of the inner surface of the folds of the capsule to which they are attached; these cells or moulds give a subtransparent bluish tint to the enamel pulp. The true inner part of the capsule forms those thick transverse folds or partitions which support the enamel organ, and with it fill the interspaces of the dentinal pulps. With regard to the formation of the cement, Cuvier, after citing the opinion of Tenon — that it was the result of ossification of the internal layer of the capsule, and that of Blake — that it was a deposition from the opposite surface of the capsule to that which had deposited the enamel, states his own conviction to be that the cement is produced by the same layer and by the same surface as that which has produced the enamel. The proof alleged is, that so long as any space remains between the cement and the external capsule, that space is found to contain a soft internal layer of the capsule with a free surface next the cement. The phenomena could not, in fact, be otherwise explained according to the "excretion theory" of dental development. To the obvious objection that the same part is made, in this explanation, to secrete two different products, Cuvier replies, that it undergoes a change of tissue: "Whilst it yielded enamel only it was thin and transparent; to give cement it becomes thick, spongy, and of a reddish colour." * The external characters of the enamel organ and cement-forming capsule are correctly defined; only, the one, instead of being converted into the other, is in fact changed into its supposed transudation: the enamel fibres being formed, and properly disposed in the direction in which their chief strength is to lie, by the assimilative properties of the pre-arranged elongated prismatic non-nucleated cells, which take from the surrounding plasma the required salts and compact them in their interior.

Whilst this process is on foot, and before the enamel fibres are firm in their position, the capsule begins to undergo that change which results in the formation of the thick cement; the calcifying process commences from several points, and proceeds centrifugally, radiating therefrom, and differing from the ossification of bone chiefly in the number of these centres, which, though close to the new-formed enamel, are in the substance of the inner vascular surface of the capsular folds. The cells arrange themselves in concentric layers around the vessels, and act like those of the enamel pulp in receiving into their interior the bone-salts in a clear and compact state; during this process they become confluent with each other, their primitive distinctness being indicated only by their persistent granular nuclei, which now form the radiated Purkinjian corpuscles. The interspaces of the concentric series of confluent cells become filled with the calcareous salts in a rather more opaque state, and the conversion of the capsule into cement goes on, according to the processes more particularly described in the Introduction to my "Odontography," until a continuous stratum is formed in close connection with the layer of enamel.

The uncalcified part of the capsule, always much softer than cartilage, is very readily detached from the calcified part, and to the naked eye the separated surface seems entire, and might readily pass, as with Cuvier, for a secreting surface. But the fine vascular processes which have been torn from the medullary canals of the calcified part are conspicuous, and resemble villi, when the detached surface is examined, even with a moderate magnifying power, under water.

Calcification extending from the numerous centres, the different portions coalesce and progressively add to the thickness of the cement until all the interspaces of the coronal plates and the whole exterior of the crown is covered with the bone-like substance. The enamel-pulp ceases to be developed at the base of the crown, but the capsule continues to be formed *pari passu* with the partial formation of the pulp, as this continues, progressively contracting, from the base of the crown, to form by its calcification the roots. The calcification of the capsule going on at the same time, a layer of cement is formed in immediate connection with the dentine. The circumscribed spaces at the bottom of the socket to which the capsule and dentinal pulp adhere, where they receive their vessels and nerves, and which are the seat of the progressive formation of these respective moulds of the two dental tissues, become gradually contracted, and subdivided by the further localisation of the reproductive forces to particular spots, whence the subdivision of the base into roots. The surrounding bone undergoes corresponding modifications, growing and filling up the interspaces left by the dividing and contracting points of attachment of the residuary matrix. All is subordinated to one harmonious law of growth by vascular action and cell-formation, and of molecular decrement modifying form by absorption. Mechanical squeezing or drawing out have no share in these changes of the pulp or capsule; pressure at most exercises only a gentle stimulus to the vital processes. Cuvier believed that there were places where the dentinal pulp and the capsule were separate from each other. I have never found such except where the enamel-pulp was interposed between them in the crown of the tooth, or where both pulp and capsule adhered to the periosteum of the socket, below the crown.

* "Seulement elle change de tissue: tant qu'elle ne donnait que de l'émail, elle était mince et transparente; pour donner du cortical elle devient épaisse, spongieuse, opaque et rougeâtre." — Annales du Muséum, tom. viii. p. 99; Ossemens Fossiles, ed. 1834, 8vo. tom. i p. 514. Art. PACHYDERMATA, p. 869.

Cuvier affirms that the number of fangs of an elephant's molar depends upon the number of points at which the base of the gelatinous (dentinal) pulp is attached to the bottom of the capsule; and that the interspaces of these attachments constitute the under part of the crown or body of the tooth, the attachments themselves forming the first beginnings of the fangs. True to his hypothesis of the formation of the dental tissues by excretion, he says * that the elongation of the fangs is produced by two circumstances: first, the progressive elongation of the layers of osseous substance (dentine) which force the tooth to rise and emerge from its socket; secondly, the thickening of the body of the tooth by the addition of successive layers to its inner surface, which, filling up the interior cavity, leaves scarcely room for the gelatinous pulp, and forces it down into the interior of the roots.

This pulling up of the fang on the one hand, and squeezing down the pulp on the other, are forces too gross and mechanical to be admitted in actual physiology to explain the growth of the root of a tooth or of any other organised product; such modes of explanation were, however, inevitable in adopting the excretion theory of dental development.

With regard to the homologies of the complex molars of the Proboscidian quadrupeds, a species of insight which may come to be deemed, in the course of anatomical science, as of equal import to the knowledge of the formative processes of parts, I must admit that the mere fact of the marked and disproportionate increase of size of the first of the three last molars over its predecessor — the last of the first three that are developed — may appear but a feeble support to the analogical evidence on which, chiefly, I have classed the three last developed molars of the elephant, in a category distinct from that of their smaller predecessors. But the value of such indication and analogy will begin to be apparent when we examine the condition of dental development in the primeval forms of Proboscidians. I have already shown that the typical character of the Diphyodont dentition was more closely and generally adhered to in the genera that existed during the oldest tertiary periods in geology than in their actual successors: it became of course highly interesting to inquire whether the miocene Mastodons, the earliest of the great Proboscidian quadrupeds of which we have any cognizance, manifested any analogous closer adhesion to type than their elephantine successors, and whether they would afford any actual proof of the true deciduous nature of the first, second, or third molars, by the development of a vertical successor or premolar. Cuvier first ascertained the fact, though without appreciating its full significance, in a specimen of the upper jaw of the *Mastodon angustidens* from Dax, in which the second six-lobed deciduous molar was displaced by a four-lobed or quadricuspid premolar developed above it and succeeding it vertically.* The same important fact was subsequently confirmed by Dr. Kaup in observations of the *Mastodon longirostris* of the miocene tertiary deposits of Eppelsheim.†

This satisfactorily proves the true deciduous character of the first and second molars; and that the third molar in order of appearance ‡, is also one (the last) of the deciduous series, is indicated by the contrasted superiority of size of the ante-penultimate tooth, which I regard as the first of the true molar series.

The great extent and activity of the processes of dental development required for the preparation of the large and complex true molar teeth would seem to exhaust the power, which, in ordinary Pachyderms, is expended in developing the vertical successors of the deciduous teeth. In the primeval Mastodons above cited, this normal exercise of the reproductive force was not, however, wholly exhausted, and one premolar, of more simple form than its deciduous predecessor, was developed on each side of both jaws. But even this trace of adherence to the archetypal dentition is lost in the more modified Proboscidians of the present day.

Another and very interesting mark of adhesion to the archetype is shown by the development of two incisors in the lower jaw in the young of some of the Mastodons, by the retention and development of one of these inferior tusks in the male of the *Mastodon giganteus* of North America, and by the retention of both in the European *Mastodon longirostris*. No trace of these inferior homotypes of the great premaxillary tusks have been detected in the fœtus or young of the existing elephants.

In the gigantic *Dinotherium* the upper incisors were suppressed, and the two lower incisors were developed into huge tusks, which curved down from the symphysis of the massive under jaw. Most of the grinders had two transverse ridges on the crown, as in the Tapir; two deciduous molars, if not three, were succeeded vertically by two premolars, the second of which (*p*. 4 of the typical series) closely resembles the true molars, as in other Perissodactyles.

The typical dentition is departed from in the existing Hippopotamus by the early loss of *p*. 1, and the reduction of the incisors to $\frac{2-2}{2-2}$ in both jaws: in the extinct Hippopotamus of India *p*. 1 was longer retained, and the

* "Ces racines et les pédicules qui leur servent de noyaux s'alongent ensuite par deux raisons: d'abord les progrès des lames de substance osseuse qui, s'alongeant toujours, forcent la dent à s'élever et à sortir de l'alvéole; ensuite l'épaississement du corps de la dent par la formation des couches successives qui, en remplissant le vide intérieur, n'y laissent presque plus de place pour le noyau gélatineux, et le refoulent vers l'intérieur des tubes des racines." Annales du Muséum, viii. 1807, p. 108; Ossem. Fossiles, 1834, p. 527.

* Ossemens Fossiles, 4to.; Divers Mastodontes, pl. iii. *fig*. 2.

† Ossemens Fossiles de Darmstadt, 1835, pl. 1.

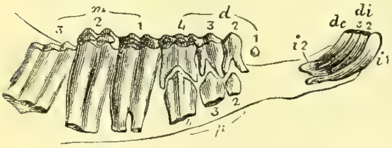
‡ Odontography, pl. 144, *fig*. 11, *d*. 3

incisors were in normal number $\frac{3-3}{3-3}$; whence the term *Hexaprotodon* proposed for this interesting restoration by its discoverers, Cautley and Falconer.

I have before remarked that the even-toed or artiodactyle *Ungulata* superadd the characters of simplified form and diminished size to the more important and constant one of vertical succession in their premolars. These teeth in the Ruminants, *e. g.* (*fig.* 580., VII., Moschus, *p.* 2, 3, 4), represent only the moiety of the true molars, or one of the two semi-cylindrical lobes of which those teeth consist, with at most a rudiment of the second lobe, as Cuvier very accurately describes *, and F. Cuvier figures in pl. 94. of his useful work, "Dents des Mammifères." An analogous morphological character of the premolars will be found to distinguish them in the dentition of the genus *Sus* (figured in my "Odontography," pl. 140., *figs.* 1 and 2), in the Hippopotamus (ib. pl. 143.), and in the *Phacochœrus* (ib. pl. 141.), where the premolar series is greatly reduced in number: yet this instance of a natural affinity manifested in so many other parts of the organisation of the artiodactyle genera has been overlooked in F. Cuvier's work above cited, although it is expressly designed to show how such zoological relations are illustrated by the teeth. Confiding in the accuracy of the Baron Cuvier's division of the hoofed quadrupeds into "Pachyderms" and "Ruminants," M. F. Cuvier separates the non-ruminant Artiodactyles from the ruminant genera of the same natural division by interposing the Tapir, Hyrax, Rhinoceros and Elephant; whilst the horse, which, in the size and complexity of its premolars, as well as in many other characters, agrees closely with the other perissodactyle Pachyderms, is placed in close juxtaposition with the Ruminants.†

Most of the deciduous molars of the Ruminants resemble in form the true molars; the last, *e. g.* (*fig.* 593., *d.* 4), has three lobes in the lower jaw ‡ like the last true molar (*m.* 3.). They

Fig. 593.



Permanent and deciduous teeth, Sheep (Ovis). (*Lower jaw.*)

are three in number on each side, and, being succeeded by as many premolars, the ordinary permanent molar formula is $p. \frac{3-3}{3-3}$, $m. \frac{3-3}{3-3}$: but there is a rudiment of *d.* 1 in the embryo fallow-deer, and in one of the most ancient of the extinct Ruminants (*Dorcatherium*, Kaup) the normal number of premolars was fully developed.

Sufficient, it is hoped, has been adduced to prove that the molar series of the Diphyodonts is naturally divisible into only two groups, premolars and molars; that the typical number of these is $\frac{4-4}{4-4}$, $\frac{3-3}{3-3}$; and that each individual tooth may be determined and symbolised throughout the series, as is shown in the instances under cut 580. If anything were wanting to prove the artificial character of a three-fold division of these teeth, and the futility of any other classification than that founded upon development, it would be afforded by the attempt to determine the homologous teeth which is exemplified by the dotted line which traverses the series, and which crosses the teeth distinguished by the name "principales" in the great "Ostéographie and Odontographie" now in course of publication by Prof. de Blainville.

This author abandons the classification of the molar series adopted by the Cuviers, without assigning his objections to it; and proposes another, in which he divides the series into "avant-molaires, principales, and arrière-molaires;" he exemplifies this division by the human dentition, in which the five grinders on each side of both jaws are formulised as "deux avant-molaires, une principale, et deux arrière-molaires." *

With regard to the characters of these kinds of teeth, the avant-molaires are "simple or complex," the principale is "trenchant," and the arrière-molaires are "tuberculous." † But as shape is not a constant character, especially in the "principale," the author proposes another from its position, describing it as "being implanted below the root of the zygomatic process of the maxillary bone" in the upper jaw; and stating that the tooth which opposes it below, and is in advance of it, or crosses in front of it, is the lower "principale."

In defining the dentition of the genus *Felis* ‡, M. de Blainville accordingly assigns 1 "avant-molaire," 1 "principale," and 2 "arrière-molaires" in the upper jaw; and 1 "avant-molaire," 1 "principale," and 1 "arrière-molaire" in the lower jaw. In another part of the same work §, he, however, proposes another formula, viz., 2 "avant-molaires," 1 "principale," and 1 "arrière-molaire" above; 1 "avant-molaire," 1 "principale," and 1 "arrière-molaire" below; but, taking either of these determinations, or the dental formulæ which he assigns to other carnivorous genera, and comparing them with his formula of the

* Ossemens Fossiles, 4to, tom. iv. p. 6.

† See my "Remarks on the Classification of the Hoofed Quadrupeds" in "Quarterly Journal of the Geological Society," May, 1848.

‡ When, therefore, the third grinder of the lower jaw of any new or rare Ruminant shows three lobes, the crowns of the premolars should be sought for in the substance of the jaw below these, and above their opponents in the upper jaw; and thus the true characters of the permanent dentition may be ascertained.

* Ostéographie, tom. i. p. 43.

† Ib. p. 43.

‡ Ostéographie des Carnivores, p. 69.

§ Ostéographie des Félis, p. 55.

molar series in the Quadrumana and Man, we find that a tooth which displaces and succeeds a milk-tooth in one species is made the homologue of a tooth, which, in Man and Quadrumana, rises above the gum without displacing any predecessor: in other words, the "principale" is a premolar in certain genera, and a true molar in other genera. I may refer to my Paper on the Classification of the Molar Teeth in the "Annales des Sciences,"* and to the concluding pages of the chapter on the teeth of the Carnivora in my "Odontography" (p. 514), in proof that a "molaire principale" does not exist in nature; that the characters by which it is defined by M. de Blainville are artificial; and that they fail in their application to determine the teeth in the series of placental Mammalia with deciduous and permanent teeth.

In the series of figures, *fig.* 580., the continuous line traverses the tooth or its homologue, in Man and the Ruminant, which Cuvier distinguished as the "molaire carnassière:" the dotted line traverses that tooth which M. de Blainville distinguishes as the "molaire principale:" the letters and numbers symbolise the teeth and indicate their individual homologies, and the binary division of the molar series, which it has been one object of the present Article to illustrate. I shall conclude it by showing how these symbols may be applied to the exposition of facts in the comparative anatomy of the teeth, and for that purpose select the complex and intricate subject of the succession of the teeth in the kangaroo.

The chief modifications of the marsupial dentition are described and illustrated in the article MARSUPIALIA (Vol. III. pp. 258—298.). When that volume was published I had not had the means of tracing the period and order of the development and succession of the entire series of teeth in any of the marsupial genera. The first of the five grinding teeth on each side of the jaws of the wombat had shown, by its displacing a milk-tooth vertically, that it was a premolar; and the adjoining molar, by its earlier development and use, was plainly the first of the four true molar teeth. In the carnivorous and insectivorous families, the marked difference of form and size of the last four teeth from those intervening between them and the canines, had also induced me to class them as true molars, although I had not got the developmental evidence of the fact, except in the case of the Kangaroos and Potoroos (*Macropus* and *Hypsiprymnus*). The analogy, however, seemed to be sufficient to justify the generalisation that the Marsupial differed from the Placental Diphyodont mammals in having four true molars, *i. e.*, $m. \frac{4-4}{4-4}$ instead of $m. \frac{3-3}{3-3}$; and also that they differed in having only three premolars, *i. e.* $p. \frac{3-3}{3-3}$ instead of $p. \frac{4-4}{4-4}$; the typical number of the grinding series, $\frac{7-7}{7-7}$, being the same. The genus *Myrmecobius* offered the most remarkable exception here, as the Manatee had done in the placental series, in the increased number of the grinding teeth, *e. g.* to $\frac{8-8}{9-9}$ or $\frac{9-9}{9-9}$, which, according to the shape of the crowns, were divided, in the *Myrmecobius*, into $p. \frac{3-3}{3-3}$, $m. \frac{6-6}{6-6}$; but the order of development and succession may show that the number of premolars is greater, and that of the true molars less. The probably marsupial *Thylacotherium* or *Amphitherium* from the Oxford oolites — the most ancient of all known mammals — had as many as twelve teeth in each molar series, besides a canine and three incisors, and by their form I have grouped them as: $i. \frac{3-3}{3-3}$, $c. \frac{1-1}{1-1}$, $p. \frac{6-6}{6-6}$, $m. \frac{6-6}{6-6}$.*

An interesting field of observation still remains open in regard to the period and order of developement of the deciduous and permanent teeth, in the different carnivorous, omnivorous, insectivorous, and frugivorous Marsupials. At present I have ascertained the required facts only in the herbivorous family (*Poephaga*).

The permanent dental formula of both the *Macropodidæ* and *Hypsiprymnidæ* is, $i. \frac{3-3}{1-1}$, $c. \frac{1-1}{0-0}$, $p. \frac{1-1}{1-1}$, $m. \frac{4-4}{4-4} = 30$. The canines, which are confined to the upper jaw, are small or minute when retained; and disappear after being represented "en germe" in most of the true kangaroos.

The deciduous dentition of the great Kangaroo (*Macropus major*) is, $i. \frac{3-3}{1-1}$, $c. \frac{1-1}{0-0}$, $\frac{2-2}{2-2} = 18$. The canines are rudimental, and are absorbed rather than shed. The deciduous incisors are shed before the young animal finally quits the pouch: when this takes place, the dentition is:—

$$i. \frac{1-1}{1-1}, d.m. \frac{2-2}{2-2} = 12;$$

the upper incisors being *i.* 1, the molars *d.* 3 and *d.* 4 of the typical dentition. This stage is exemplified in the lower jaw at A, *fig.* 594. The next stage shows the acquisition of *i.* 2 in the upper jaw, and *m.* 1 in both jaws, and the formula is:—

$$i. \frac{2-2}{1-1}, d.m. \frac{2-2}{2-2}, m. \frac{1-1}{1-1} = 18. \text{ (B, \textit{fig.} 594.)}$$

At one year old, the dentition is:—

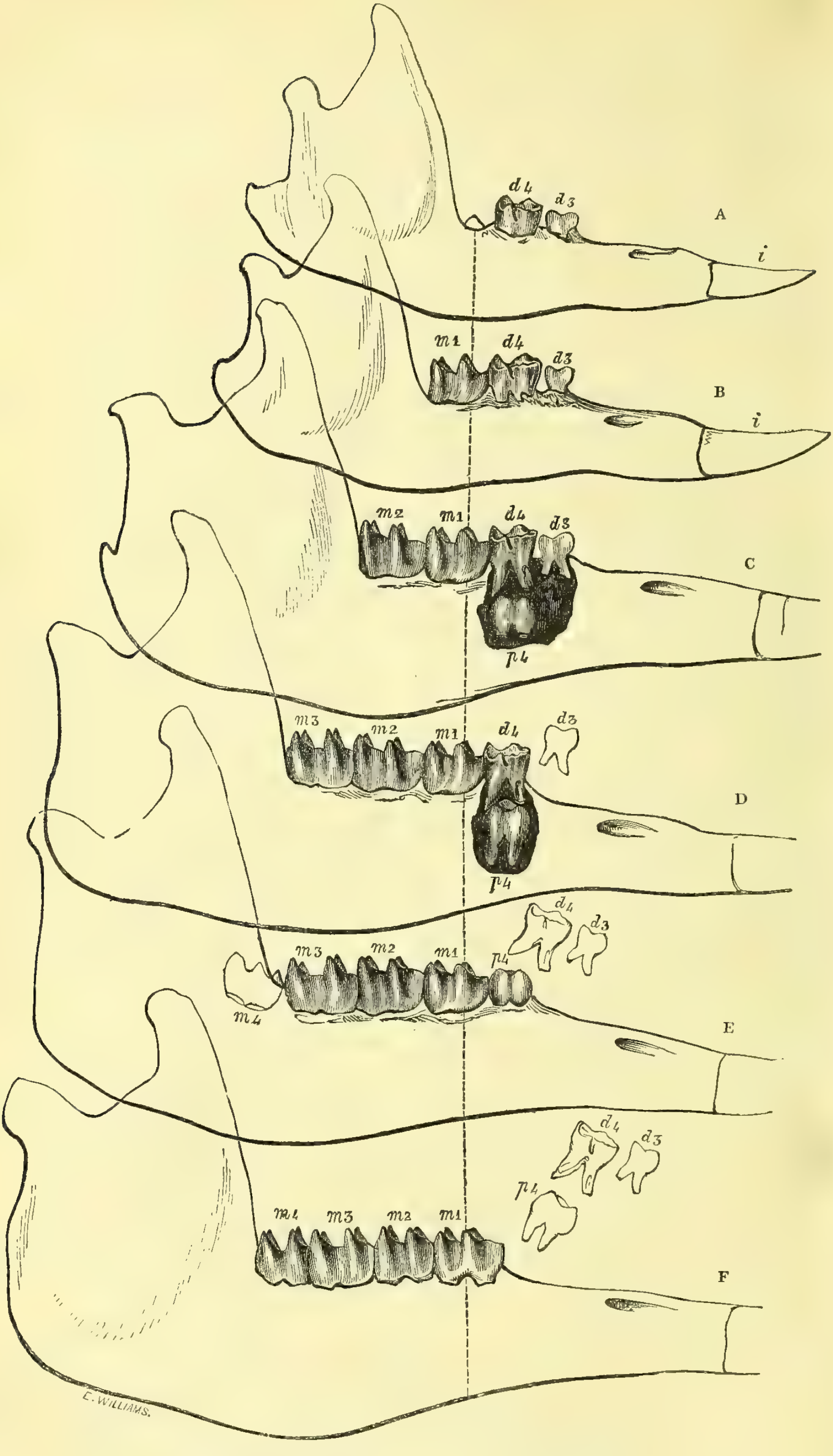
$$i. \frac{3-3}{1-1}, d.m. \frac{2-2}{2-2}, m. \frac{2-2}{2-2} = 24;$$

the additional teeth being *i.* 3 and *m.* 2 (C, *fig.* 594.; in which the demonstration of the true deciduous character of *d.* 4 and *d.* 3 is shown by the germ of their vertical successor,

* Tom. iii. (1845), p. 116.

* Odontography, p. 376, pl. 99.

Fig. 594.



Progress and change of dentition, Kangaroo (Macropus).

p. 4, which is exposed in the substance of the jaw). The next stage is the shedding of *d*. 3, and the acquisition of *m*. 3 (D, *fig*. 594.). Then *d*. 4 is shed by the ascent of *p*. 4 into its place (E, *fig*. 594.). Afterwards *m*. 4 is acquired, and, in the *Macropus gigas*, *p*. 4 is simultaneously pushed out (F, *fig*. 594.).

Thus, four individuals of this species may be found to have the same number of molars, *i.e.* $\frac{4-4}{4-4}$; two of these may seem, on a cursory comparison, to have them of the same shape, *e.g.*, like C and E, *fig*. 594.; or like D and F. In fact, to determine the identity or difference in such instances, it requires that the substance of the jaws be examined to see if the germs of successional teeth be present, as at *p*. 4, C and D, or at *m*. 4, E.

The result of such examination may be to show that not one of the four kangaroos with the *m*. $\frac{4-4}{4-4}$ had the same or homologous teeth. The four grinders, *e.g.*, may be—

d. 3, *d*. 4, *m*. 1, *m*. 2; as in C: or,
d. 4, *m*. 1, *m*. 2, *m*. 3; as in D: or,
p. 4, *m*. 1, *m*. 2, *m*. 3; as in E: or,
m. 1, *m*. 2, *m*. 3, and *m*. 4; as in F.

But the change does not stop here: as age advances, *m*. 1 is shed, and the molar series is reduced numerically to the condition of B; but, instead of *m*. 1, *d*. 4, and *d*. 3, it consists of *m*. 2, *m*. 3, *m*. 4.

Finally, *m*. 2 is shed, and the dentition is reduced to the same numerical state as at A, *fig*. 594.: the teeth, however, being *m*. 3 and *m*. 4.

The order here described is not precisely that which is followed in some of the smaller species of kangaroo. In *Macropus Benettii*, *e.g.*, the acquisition of *m*. 3 is not accompanied by the shedding of *d*. 3, but the molar series is numerically $\frac{5-5}{5-5}$: so, likewise, in this species, the acquisition of *m*. 4 is not accompanied by the displacement of *p*. 4; and a molar series of $\frac{5-5}{5-5}$ is long retained; but, at the earlier period cited, the teeth are:—

d. 3, *d*. 4, *m*. 1, *m*. 2, and *m*. 4:

and, at the later period, they are:—

p. 4, *m*. 1, *m*. 2, *m*. 3, and *m*. 4.

These symbols, it is hoped, are so plain and simple as to have formed no obstacle to the full and easy comprehension of the facts explained by means of them. Had those facts been described in the ordinary way, by means of verbal phrases or definitions of the teeth,—*e.g.*, "the second deciduous molar, representing the fourth in the typical dentition," instead of *d*. 4, and so on,—the description would have occupied much more space, and have levied such a tax upon the attention and memory, as must have tended to enfeeble the judgment, and impair the power of seizing and appreciating the results of the comparisons.

Each year's experience strengthens my conviction that the rapid and successful progress of the knowledge of animal structures, and of the generalisations deducible therefrom, will be mainly influenced by the determination of the nature or homology of the parts, and by the concomitant power of condensing the propositions relating to them, and of attaching to them signs or symbols, equivalent to their single substantive names. In my work on the "Archetype of the Skeleton," I have denoted most of the bones by simple numerals, which, if generally adopted, might take the place of names; and all the propositions respecting the centrum of the occipital vertebra might be predicated of 1 as intelligibly as of "basioccipital."

The symbols of the teeth are fewer, are easily understood and remembered, render unnecessary the endless repetition of the verbal definition of the parts, harmonize conflicting synonyms, serve as a universal language, and express the author's meaning in the fewest and clearest terms. The entomologist has long found the advantage of such signs as ♂ and ♀, signifying male and female, and the like; and it is time that the anatomist should avail himself of this powerful instrument of thought, instruction, and discovery, from which the chemist, the astronomer, and the mathematician have obtained such important results.

(*R. Owen.*)

TEMPERAMENT. Although all individuals of the same species are composed of the same tissues, consisting of the same elements both proximate and ultimate, and agreeing in all essential points of chemical constitution, yet there exist between certain groups of them, sometimes in the most striking degree, differences not only in the physical powers and actions of their frames, but also in their mental qualities. These differences are referrible only to peculiarities in the constitution of an individual, or in other words, to peculiarities in the quality of his solids and fluids, which are of a nature so recondite that we cannot detect them by any chemical or anatomical means, and we appreciate them only by the character with which they impress the physical and, to a certain extent, mental actions of the individual in which they exist. To express this character in one word physiologists employ the term *temperament*.

The use of this word is of very ancient date. We trace it as far back as the time of Galen, who broached the doctrine that the blood consisted of four humours, corresponding to the four elements; these were respectively designated *bilis*, *sanguis*, *atra bilis*, *phlegma*. Nunc, says Haller, ex ejusmodi quatuor humoribus sanguinem aiebant *temperari*, justamque omnium principiorum commistionem perfectissimum *temperamentum* efficere; si vero aut sanguis supra legitimam suam quasi dosin abundaret, sive bilis, sive terra atrave bilis, sive phlegma, quatuor tunc simplicia et præcipua temperamenta aiebant oriri, a bilis abundantia *cholericum*, ab aquæ ubertate *phlegmaticum*, a sanguinis aucta portione *sanguineum,* et denique a copia atræ bilis *melancholicum.**

This view of the doctrine of temperaments prevailed in the schools down to the time of Cullen, and we find that able and thoughtful physician thus expressing himself upon the subject: "The ancients very early established a distinction of temperaments which the schools of physic have almost universally adopted ever since, and appears to me to be founded on observation. I am very much of opinion, that we can perceive a combination of a particular state of the chief circumstances of the economy to take place very steadily in certain persons, and thereby to form at least two of the temperaments assigned by the ancients."†

The temperaments, the existence of which seems most consistent with observation, are those admitted by Cullen, namely, *the sanguineous* and the *melancholic*, the *phlegmatic* being a degree or modification of the sanguineous, and the *choleric* of the melancholic.

It is reasonable to expect an infinite variety as regards the extent to which the characteristic marks of the temperaments are manifested in various individuals. Taking examples which afford good indications, the two temperaments above referred to may be described as follows, after Cullen.

Individuals of the sanguine temperament have the quantity of fluids in the body large in proportion to the solids, the habit of body soft and plump, after the period of manhood disposed to obesity, and at all times, readily sweating upon exercise, the skin smooth and white, the hair soft, generally of a pale colour or from thence passing through different shades to a red; the complexion ruddy, the eyes commonly blue; the strength of the whole body is moderate, and the mind sensible, irritable, cheerful, and unsteady. The most exquisite examples of this temperament are found in men from the time of puberty to that of manhood, and in women. In both sexes the characteristics of the temperaments are far less manifest in old age.

In persons of the melancholic temperament the habit of the body is rather hard and meagre, the quantity of fluids in the whole system moderate in proportion to the solids, the simple solids firm and dense, the hair hard, black, with a tendency to curl, the skin coarse, of a dun colour, with a corresponding complexion, the eyes very constantly black, the strength considerable, the mind slow, disposed to gravity, caution and timidity, with little sensibility or irritability, but tenacious of all emotions once excited, and therefore of great steadiness. This temperament is most completely formed in advanced life, but the characters of it appear often very early.‡

By some writers a *nervous* temperament is admitted, the prominent characteristic of which consists in a great excitability of the nervous system, and a predominance of emotional impulses over the influence of the will. Individuals of this temperament are generally fidgetty and restless, take but little sleep, and are anxious about trifles; they are called "creatures of impulse;" their emotions are easily excited, and often not readily subdued. In persons of this temperament, when labouring under disease, phenomena referrible to the nervous system are very apt to complicate and often to obscure the morbid actions. This temperament, however, cannot be said to exist apart from the sanguineous or melancholic: it always accompanies either one or the other, most frequently the former, and the most exquisite examples of it are found in the female sex.

In looking at the physical conditions of the best-marked examples of the sanguine and melancholic temperaments, it is important to ascertain whether any one property or quality stands out more prominently than the rest, which might seem to give to the whole economy of the individuals its peculiar cast. It appears to me that there is no single physical property which is so closely associated with difference of temperament as variety in the quantity, and perhaps also in the kind, of colouring matter or pigment, evinced by the colour of the hair and skin, and influencing also the colour of the eyes, and of the blood, and of the nervous centres.

Individuals of the melancholic temperament exhibit in their various tissues a considerable amount of pigment, as shown by the dark colour, generally black, of the hair and eyes, while on the other hand those of the sanguine temperament are deficient in colour, having light hair, blue or grey eyes, and fair or white skins. Observations are yet wanting, in sufficient number, to determine the relative amount of colouring matter in the blood of individuals of each of these temperaments, or to ascertain whether it is characterised by any peculiar chemical qualities. It seems highly probable that the amount and kind of colouring matter in the skin, hair, and eyes, as well as of that in some of the secretions, as bile, urine, &c. is influenced by the amount and kind of the hæmatine.

The xanthous and leucous races of man inhabiting for the most part cold or temperate climates, afford the most numerous examples of the sanguine temperament, while the melano-comous or dark races found chiefly in warm climates are mostly of the melancholic temperament. And those individuals of the xanthous and leucous races, which in physical characters approach most nearly to the dark races, as by the existence of a large quantity of dark pigment in their tegumentary tissues, are of the melancholic temperament, whilst the light-coloured members of the xanthous races are prone to exhibit the characters of the sanguine temperament.

If it be admitted that a constant connection exists between colour and temperament, as I think is sufficiently obvious, it would follow that the nature of the temperament is determined by certain peculiarities in the physical

* Haller, El. Physiolog. lib. v. sect. 4.
† Mat. Med.
‡ Cullen, loc. cit.

condition of the frame. These peculiarities react to a certain extent upon the mind, and more or less aid or clog its workings, but certain powers and modes of action of the mind are by no means so constantly associated with certain states of body, as to connect the mental and bodily states as cause and effect. It is true that the sanguine temperament is generally accompanied by a mind exhibiting certain characters, but the exceptions to this are so numerous that we cannot assign the corporeal state as the cause of the mental — nor *vice versâ*. Bodily peculiarities are infinitely more frequently inherited than mental, — the powers and activity of the mind are greatly determined by education and training; but those qualities of body which give a character to its temperament are born with it; and although they may be modified by external influences, they are yet at all times sufficiently distinct to prove them to be inherent physical properties of the entire organism.

At the same time it seems reasonable to admit that the mind has its temperaments, as the body has, and in a great measure independently, and the terms, sanguine, melancholic, phlegmatic, and choleric, may be severally applied to them, according as the emotions and feelings, and the intellectual actions vary in their modes and degrees of developement, and in their rate of working.

(*R. B. Todd.*)

TEMPORO-MAXILLARY ARTICULATION.

TEMPORO-MAXILLARY ARTICULATION.—Under this heading I propose to give a brief account of the jointing of the lower maxilla to the cranium. This joint cannot, of course, be identified out of the *vertebrata*. The mandibles and maxillæ of the *articulata* are not homologous with the jaws of vertebrate animals, and the slit of their mouths is placed vertically not horizontally.

In the *human subject*, as in all *mammalia*, this articulation takes place between the squamous portion of the temporal (*squamosal*) and the inferior maxillary bones. The description of the anatomy of the human temporo-maxillary joint comprises, therefore, that of the diarthrodial articular surfaces of those bones, and also of the following parts: viz., the interarticular fibro-cartilage, the two synovial sacs, the external and internal lateral and other ligaments, and part of the insertion of the external pterygoid muscle.

Bones. — The articular condyle of the lower jaw is sub-cylindroid in form, its length from side to side being greater than its antero-posterior measurement. The axis of this cylinder, however, is set neither directly from side to side, nor yet exactly level, its inner part being posterior to and below its outer; so that if the axes of the two condyles were produced inwards till they met, they would form an angle in doing so, which would point downwards and backwards, — reaching the anterior margin of the foramen magnum. The cartilage that encrusts this condyle extends further down behind than in front.

The surface to which this condyle is (mediately) articulated forms a part of the glenoid fossa, and is situated just below the base of the zygomatic process of the temporal bone, between its roots. It has such form as, in respect of the set of its axis, and its tranverse measurement, pretty accurately fits the condyle. It has, however, a greater antero-posterior extent, in accordance with the capability which this joint normally possesses, in addition to the usual ginglymoid motion, of an antero-posterior gliding to and fro of the condyle — a kind of normal dislocation. The glenoid fossa of the temporal bone contains a portion of the parotid gland, as well as the condyle of the inferior maxilla; the former occupies that portion of it which is posterior to the glasserian fissure, whilst that part which is anterior to the glasserian fissure, is lined with cartilage for the articulation of the latter. In man there is usually no bony ridge bounding this articular surface posteriorly, such as is generally found in the lower mammalia.

The ridge that bounds it anteriorly is formed by the inferior root of the zygoma, and the cartilage is continued some way on to this ridge. Externally it is limited by a tubercle on the zygoma, which serves for the attachment of the external lateral ligament of the joint.

Interarticular fibro cartilage. — This is a thin disc or meniscus, oval or sub-oblong in form, concave below and convex above, thus capping the condyle, thicker at the edges than in the middle, where it is not unfrequently thinned away even to perforation. It differs from all the other fibro-cartilages in having muscular fibres inserted into it; namely, a portion of those of the external pterygoid. This insertion takes place along its anterior border, and by it the fibro-cartilage is made to join in that normal amount of dislocation forwards, which as above stated, the condyle of the lower maxilla is capable of, as well as in the abnormal accidental dislocation of the jaw. It is further held in its place by the fibres of the external lateral ligament, and by the synovial bursæ of the joint.

Synovial Bursæ. — These are two in number, one above the interarticular fibro-cartilage and the other below it. The upper one is the larger and slacker, for it alone is concerned in the antero-posterior gliding of the joint. The two sacs, of course, communicate and are reduced to one when the interarticular fibro-cartilage is perforated in the centre.

Ligaments.—There is only one ligament in immediate relation with the temporo-maxillary joint, namely, the *external lateral.* This is a small ligament, broader above than below, situated at the outside of the joint; attached above to the tubercle situated at the point of divergence of the roots of the zygoma; and directed downwards and backwards to the outside of the neck that supports the condyle of the lower jaw. Midway in its passage from the one to the other it is attached by its inner aspect to the interarticular fibro-cartilage.

The *internal lateral ligament* is a long thin slip extending from the spinous process of the sphenoid, and the neighbouring parts of the temporal bone to the fore part of the lip of the inferior dental canal. It lies behind the external pterygoid muscle, by the origin of which its cranial attachment is concealed, and it is separated from the temporo-maxillary joint by a considerable space through which pass the internal maxillary artery and vein, giving off their middle meningeal and inferior dental branches, which indeed are conducted, the former to the foramen spinosum of the sphenoid, the latter to the inferior dental canal, by the ligament in question.

Numerous stray fibres of ligamentous tissue strengthen the synovial sacs of the temporo-maxillary joint, forming a kind of *capsular ligament.*

That process of the cervical fascia, which is called the *stylo-maxillary ligament*, is generally enumerated as one of the ligaments of this joint. It extends from the styloid process to the lower part of the ramus of the jaw, separating the parotid from the submaxillary gland, and affording attachment to the stylo-glossus muscle. The condyle of the lower jaw depends for the maintenance of its normal apposition to the temporal bone much more upon the masseter, temporal and pterygoid muscles than upon these small ligaments; by these, however, its astero-posterior gliding is indifferently tethered.

Muscles. — The *external pterygoid-muscle*, proceeding backwards and outwards from its origin, is mainly inserted into the front of the neck that supports the maxillary condyle, the upper part of it, however, is inserted into the interarticular fibro-cartilage, which thereby is drawn forward along with the condyle when this muscle acts. This insertion is tendinous.

Motions of the joint. — The temporo-maxillary joint admits of a ginglymoid motion in the vertical direction, by which the mouth is opened and shut. This motion must of necessity always take place in the joints of both sides at the same instant. It also admits of a horizontal antero-posterior gliding motion, in which the joint of one side only may be mainly concerned. In the human subject the front teeth of the lower jaw, in most cases, are not exactly opposed to those of the upper jaw—that is, the summits of the one set are not applied to the summits of the other — in the ordinary position of the mouth, either when at rest or engaged in mastication. The lower incisor teeth are usually posterior to the upper. But when we bite with the front teeth we bring the upper and lower set into apposition by thrusting forward the lower jaw : in this act both joints are similarly concerned. We can also execute a grinding motion from side to side, and this is done by thrusting forward one condyle whilst the other merely revolves on the axis of its neck.

The jaw is *elevated* or closed by the temporal, masseter, and pterygoid muscles. The pterygoid, chiefly the external, are the agents in *protruding* it. These latter are antagonised by the elevating and also by the depressing muscles. The chief *depressor* of the lower jaw is the digastric, as is clearly shown by its comparative anatomy, but all those which extend from the chin to the hyoid bone are capable of, and occasionally do assist in performing this act.

The majority of the muscular fibres that elevate the jaw arrive at their insertion into it from before backwards; thus the masseter has a kind of twist in the arrangement of its fibres, so that those which arise most anteriorly are inserted very conspicuously furthest back, whilst the remainder proceed directly downwards or slightly forwards; a considerable portion of those of the temporal, namely, those which arise from the anterior part of the temporal fossa, run *backwards* to their insertion into the coronoid process. The use of this arrangement seems, upon a careful consideration of the mechanics of the question, to be the application of the elevating or closing force in a more favourable direction, not, as might seem at first sight, the protrusion of the lower jaw — that is amply effected by the *pterygoideus externus.*

Abnormal conditions of the temporo-maxillary joint.—*Accidents.*— The condyle of the lower jaw can only be *dislocated* in one direction, namely forwards. In this accident the condyle slips forward over the inferior root of the zygoma, and is then drawn somewhat upwards within the zygomatic arch. The inter-articular cartilage is carried with it. This usually happens to the joints of both sides, but occasionally one condyle only is dislocated. It is usually produced by the action of the muscles when the mouth is very widely opened, as in yawning, or more especially in biting a very large object, such as a large apple.

When both the condyles are dislocated, the lower jaw is thrust forwards and cannot be retracted. The mouth is widely open and the patient is unable to close it. The power of swallowing is lost, and the saliva, the secretion of which is probably increased, flows from the mouth involuntarily. Articulation is difficult, owing to the impossibility of making the labial sounds. There is a conspicuous depression beneath the zygoma just in front of the ear, and a flatness in the masseteric region. The coronoid process is much depressed, and forms a visible protuberance beneath the zygoma, and, as first observed by Mr. Adams of Dublin, there is a prominence in the temporal region between the eyebrow and the ear, produced by the posterior fibres of the temporal muscle being pushed up by the condyle in its new position.

If this dislocation remains unreduced, the parts, as in most other dislocations, gradually accommodate themselves to their new position, so that the power of articulation and deglutition is re-acquired, the mouth can be closed, and a considerable amount of motion is regained, but the chin remains abnormally thrust forwards, and there is always a depression in the position normally occupied by the condyle.

When one condyle only is dislocated, the chin is thrust forwards and towards one side —that, namely, on which the condyle remains in place. The coronoid process of the dislocated side forms a prominence even more conspicuous than when both condyles are displaced, but the mouth is not so wide open. There is, of course, the same depression in front of the ear, and the same flatness of the masseteric region.

Congenital malformation. Dr. R. W. Smith of Dublin, in his Treatise on Fractures and Dislocations,* gives a detailed account of the dissection of a highly interesting case of "Congenital luxation of the inferior maxilla." The malformation affected one side only, — the right,— and consisted mainly of an absence, or arrest of development of the condyle, the only vestige of which was a small process hooked inwards at its apex. This process did not touch the temporal bone by a quarter of an inch, and neither it nor the surface opposite to it presented any articular cartilage, but were both simply invested with periosteum. There was no trace of an interarticular fibro-cartilage, nor of a synovial sac, and the external lateral ligament sloped downwards and forwards instead of downwards and backwards. The glenoid cavity did not exist, or rather the inferior root of the zygoma, which really forms the glenoid cavity, was not developed. There was conspicuous atrophy of the whole of this side of the face in respect of the bones — temporal, right half of the body and right ramus of the inferior maxilla, malar, superior maxillary, and even the right half of the sphenoid, — and muscles, but the nerves were as large as their fellows. The most remarkable of the peculiarities of the surrounding parts, and that which clearly demonstrated the abnormal condition not to be the result of injury or disease, was an extreme shortness of the zygomatic process of the the temporal and a compensatory unusual length of that of the malar bone. The former was only half an inch long, whilst the latter was nearly twice as long as that of the other side. During the lifetime of this patient, who was an idiot, it was observed that one side of his countenance did not match the other, and that the disparity was much increased when he opened his mouth. He was often observed to have spasmodic twitching of the abnormal side of his face.

Disease. — *Chronic rheumatic arthritis* occasionally affects this articulation. Both joints are usually affected by it, but sometimes it attacks the joint of one side only. It is most common in elderly subjects. When it attacks the young or middle aged, it is more rapid, accompanied with more pain, and more likely to involve the neck of the condyle and the ramus of the jaw. The pain is often very severe but variable, apparently influenced by meteorological changes. The lymphatic glands in the neighbourhood of the diseased joint are much prone to enlargement; and sometimes the enlarged condyle can be felt as a bony tumour just in front of the ear. The chin is thrust forward, mesially when both joints are affected, and towards the healthy side, as well as forwards, when only one is diseased. The motion of the jaw is considerably impaired. On dissection, the condyle, in cases of this affection, is generally found to be large and broad, but sometimes conical, rough, and devoid of cartilage. Ivory or porcellanous deposit, so common in other joints when affected with chronic rheumatic arthritis, is but rarely met with in this; those abnormal ossific concretions in and around the joints, which are so constantly met with in the disease in question in other situations, have also never been found in the temporo-maxillary joint. The interarticular fibro-cartilage had disappeared in every case of this affection which has been dissected and published. The glenoid cavity is enlarged, divested of its articular cartilage, and presents a roughened, abnormal surface. All indication of the disease stops suddenly at the glasserian fissure, and at the spheno-temporal suture, and the enlargement of the glenoid cavity takes place at the expense of the lower root of the zygoma which generally becomes entirely absorbed.

In the report of the proceedings of the Pathological Socety of London in the Medical Gazette of November 30. 1849, there is an account of a highly interesting case of *necrosis* of the condyle, back part of the ramus, and angle of the lower jaw in a *scrofulous* boy. The portion of necrosed bone, which was exhibited to the society, was removed many years before, by Mr. Keate, who also had examined the patient, grown to a healthy man, two years before the date of the communication. As far as could be ascertained by external investigation, the lost portion of bone had been perfectly restored. There was no deformity, and no impairment of motion. There are two other similar cases on record; one by Desault, in which the whole ramus, with the condyle and coronoid process, were removed, the other by Mr. Syme, in which the condyle and ramus were necrosed. In both these cases, also, the lost bone was perfectly restored to all external appearance, but there is no record of a dissection of such a case. In some cases which are on record, where the whole of the lower jaw, with both its condyles, has been removed, its place has been supplied by condensed fibrous tissue, but there has been no reproduction of bone.

Anchylosis of the temporo-maxillary joint is a very rare occurrence. There is, however, one specimen of it in the Pathological series of the Museum of the London College of Surgeons. The fusion of the two bones is complete, as is shown in the preparation by a vertical, side to side, section through the situation of the quondam joint. This section shows that a perfectly normal-looking cancellous structure, shelled over by a layer of dense osseous tissue, is continued from the temporal to the inferior maxillary bone, and exhibits no

* A Treatise on Fractures in the Vicinity of Joints and on Certain Forms of accidental and congenital Dislocations. Dublin, 1847. 8vo.

manner of trace to indicate where the joint once was. In fact this anchylosis had existed for fifty years before the death of the patient. No record is preserved of the cause of it. The joint of one side only is anchylosed, but that of the other side is much altered in form. An abnormal tubercle of bone projects downwards from the middle of the glenoid cavity and is received into an abnormal excavation or alveolus in the middle of the condyle. The lower jaw is much wasted in size, and has lost all its teeth save the two front incisors. The upper jaw bones are thin and light.

The motion of the lower jaw is often lost owing to an affection not immediately connected with the joint itself. When, as often happens in scarlatina, cancrum oris, &c. there is extensive sloughing of the inside of the cheeks, the cicatrices resulting from the healing of the great wounds contract, and form bands, extending from the upper to the lower jaw, so strong and unyielding that the muscles which open the mouth are unable to antagonise them.

Comparative Anatomy.—If a palæontologist were asked what fragment of a vertebrate skeleton, speaking generally for all vertebrata, would give him most information as to the status and affinities of the animal to which it belonged, he would most probably answer — the articular portion of the lower jaw or the articulation that receives it. Of the convex and concave surfaces which go to form this articulation, in all the *mammalia* the *convexity* is on the inferior maxilla, and the concavity on the squamosal bone, whilst in the three other vertebrate classes the reverse is invariably the case — the concavity is on the inferior maxilla, the convexity on the bone that articulates with it.

The under jaw does not articulate with the same, or to speak more accurately, with the homologous bone in all vertebrate animals. In all the mammalia it articulates, as in man, with the squamous element of the temporal — the squamosal bone. In birds, reptiles, and osseous fishes it articulates with bones which are clearly the special homologues of the tympanic ring of the human subject. In cartilaginous fishes its articulation is with the pterygoid bone, the homologue of the human internal pterygoid plate. The Lepidosiren, in which so many other characters of the osseous and cartilaginous fishes are so curiously blended together, in strict accord with this circumstance, presents an instance of the pterygoid and tympanic bones contributing each a part — the former the inner, the latter the outer part, of the articular surface for the reception of the lower jaw.*

It is well worth while to stop here and review what is stated in the two preceding paragraphs. What is said is, really, this; — every animal that suckles its young has a convex articular surface to its lower jaw, whilst every vertebrate that lays eggs has a concave surface. Or this — every vertebrate animal that has hair upon it, that has a diaphragm, or an epiglottis, has a convex articular surface to its lower maxilla, whilst all vertebrates that are destitute of these have a concave surface. Or, again, all animals that suckle their young, and have diaphragms, hair, and epiglottides, present their squamosal bones for the articulation of their inferior maxillæ, whilst all in which the possession of these characters is negatived present for this articulation their tympanic. or, rarely, their pterygoid bones. Can any physiological reason be assigned for this? Can any final purpose, holding good in all, or in the majority of, instances, be shown to be served by this difference? I think none can. One cannot conceive but that it is a matter of perfect indifference whether the convexity is on this bone or that. Let us look once more to the facts. The bat that flies, but not the swallow, the whale that swims but not the cod-fish, the camel that walks the desert, but not the ostrich, the carnivorous lion, seal, and weasel, but not the eagle, penguin, crocodile, and shark, have convex articulations to their lower jaw and present to them their squamosal bones. Here then is a caveat for the physiologist. A character found in an animal may have no physiological signification,—no relation to external circumstances, nor even a functional connexion with, or dependence on other characters wherewith it coexists, perhaps invariably. It may be due to the status only of the animal. Physiologically independent it may exist in an animal only because other independent characters co-exist. It may be a *Syneilogy*, not a *Teleology*.

That certain independent characters invariably go together, which was so elaborately illustrated by Cuvier, is a fact of a high order, perhaps the twilight of some great truth. If future investigations should prove that truth to be progressive developement, towards which hypothesis the inquirer is, even now, tempted by so many striking facts, as well as by the admirable use that can be made of it as a scaffold theory, then we should say, and as making use of a scaffolding we may say it now, that certain characters are attained to at a certain stage in the chain of development, and, therefore, those are found coexisting which are proper to the degree of development to which the animal has arrived. Such characters I have been accustomed to call *Syneilogies* *, a word which at all events has the merit of referring only to a well known fact, without involving any hypothesis. To the palæontologist this "correlation of independent characters" † is, of course, invaluable, and for the purpose of arranging *natural* groups in the animal kingdom, these, so to speak, useless, or Syneilogical, characters are immeasurably more valuable than those modifications to meet special exigencies which are called teleologies.

Mammalia. — In all mammalia, except man, the articular surface on the squamosal bone is bounded posteriorly, or, in the rodents, inter-

* Owen.

* σὺν, εἰμὶ, λόγος.

† Cuvier.

nally, by a prominent ridge or process. This is the case in the higher *Quadrumana*, and there is an indication of it even in the lower races of mankind. In the *Carnivora* the condyle is in general extremely long, cylindroid, and its length is set, almost or quite directly from side to side, whilst the surface to which it is opposed is bounded by a very salient ridge fore and aft. This condition attains its acme in the *Badger*, where the salient ridges, especially the posterior, even arch over and surround the cylindroid condyle so much, that in the dry skull the lower jaw remains attached to the cranium without any artificial contrivance, and can be removed only by slipping each half out sideways when the symphysis has been disjoined. With such a joint there cannot, of course, be the usual lateral motion of the jaw. In the Rodentia, on the contrary, the long diameter of the condyle is directed antero-posteriorly, and is adapted to an antero-posterior groove, mostly bounded, internally and externally, by salient ridges. Hence that nibbling, antero-posterior motion of the jaw, which is so conspicuous in these animals, and with which their teeth and masticatory muscles are in such admirable relation. This only holds good in respect of the placental rodents. In that great *marsupial* rodent, the *Wombat*, the saliently arched, cylindroid condyles have the usual side to side and converging-behind set of their long diameters. The articular surface which is opposed to this condyle is placed, as in the placental rodents, on the zygomatic process, which in both runs almost directly outwards; instead, however, of being an antero-posterior groove it is a transverse convex cylindroid, describing a retreating curve ; so that in the temporo-maxillary joint of the wombat a cylindroid ridge is opposed to another cylindroid ridge, the one describing a salient, the other a retreating arch.* The articular facets of the temporo-maxillary joint in the *Ruminantia* approach more nearly to plane surfaces than in any other animals. The squamosal facet is bounded by a ridge posteriorly, but has no bony limitation in front. This is in relation with the extensive lateral movement of the jaw which these animals use in chewing the cud, and with the limited power of gaping which they possess. The rest of the mammalia present varieties in this joint which are extremely interesting, but an account of them would occupy more space than the limits of this work permit.

Aves. — In birds, as above stated, the articular surface of the lower mandible is concave, and is adapted to the tympanic bone, or, as the older ornithologists called it, the os quadratum.† The articular surface of the lower jaw presents two concave depressions. The tympanic bone is itself moveable, being articulated to the cranium by two diarthrodial joints, so that a bird's lower jaw is swung to the head by two moveable jointings.

Reptilia. — The evenly concave articular surface of a reptile's lower jaw is often contributed to by more than one of the osseous pieces which compose the inferior maxilla of the oviparous vertebrates. In the crocodile by two, in some chelonia by three of these pieces. The tympanic bone is articulated with the other cranial bones by suture, and is therefore immoveable, in the *Crocodilia* and *Chelonia*, but it is articulated with them by diarthrosis, and therefore moveable, in the *Lacertia*, *Ophidia*, and *Batrachia*. In some ophidia, as the *Python*, there being, properly speaking, no symphysis of the lower jaw, but instead of it an elastic ligament, holding the two halves together at the chin, one temporo-maxillary joint is capable of movement independently of the other. In the Batrachia, among their many fish-like characters is that of a dismemberment of the tympanic bone, which consists of an upper and a lower piece.

Pisces. — In the majority of fishes, the tympanic bone is represented by four separate pieces called epi-, hypo-, meso-, and præ-tympanic bones. These, further, bear upon their posterior edge three opercular bones, which were considered by Geoffroy St. Hilaire to be the homologues of the ossicula auditus, but are regarded by Prof. Owen as appendages, serially homologous with the costal appendages. The uppermost piece, the epi-tympanic, articulates by a diarthrodial joint with the mastoid, and the lowermost, hypo-tympanic, presents a diarthrodial convexity to the lower jaw. The four tympanic pieces articulate with one another, and with the opercular bones by the interposition of ligament, or rather membrane, connecting their thin adjacent edges together, so that the whole apparatus is capable of bilging outwards in the movements of respiration. In the eel tribe (*Murænidæ*) the number of tympanic bones is reduced to three, which is obviously an approach towards the two tympanic pieces of the Batrachia. The formation of the cranial part of the joint in question by the pterygoid and tympanic bones conjointly, in the *Lepidosiren* has been mentioned above. In the *Sharks* and *Rays* the tympanic pedicle descends upon that part of the pterygoid which forms the joint, but does not actually reach the articulation, the pterygoid being interposed. In these fishes, the super-maxillary and pterygoid pieces being confluent, and both bearing teeth, it appears at first sight that the whole upper jaw is formed by the former alone, consequently that the inferior maxilla is articulated directly with the super-maxillary ; such an articulation, however, never takes place in any animal.

The *interarticular fibro-cartilage* is constantly met with in *Mammalia*, but in neither of the other vertebrate classes.

Homology of the joint. — The joint in question is the articulation between the *pleurapophysis* and the *hæmapophysis* of the frontal vertebra. It is therefore serially homologous with the joint between the rib and the costal cartilage of mammalia, or the vertebral and sternal ribs of birds and reptiles.

* See Art. MARSUPIALIA, fig. 94.
† See Art. AVES.

The joints connected with the maxillary apparatus of some of the animals belonging to the three lower sub-kingdoms are, as was stated in the beginning, not homologous with this joint, although identical in function. For description of these parts see the articles ANNELIDA, ARACHNIDA, CEPHALOPODA, CIRRHOPEDA, CRUSTACEA, ECHINODERMATA, ENTOZOA, INSECTA, MYRIAPODA, and ROTIFERA.

(*S. R. Pittard.*)

TERATOLOGY. — Under this name, which we owe to Geoffroy St. Hilaire, we understand the doctrine of *congenital deformities.** In a scientific sense, it constitutes a part of Pathological Anatomy, and demands our interest as much as the knowledge of those other deviations from the normal state, which is ordinarily regarded as constituting that science. In fact, pathological anatomy comprises all the anomalies of the organization; those which occur during intra-uterine life are called *congenital*, and those which arise during extra-uterine life *acquired.* We refer to the former the imperfections of the primitive formation, or what we call monstrosities. They are those deviations of the organism which can be formed only in the earliest periods of gestation, or, at least, previously to the termination of the fœtal condition.

The opinions now held with respect to these malformations differ widely from the absurd notions which influence the descriptions given of them by Aldrovandi, Ambrose Paré, Licetus, Palfin, and Rueff. Formerly, indeed, each monstrosity was considered as the presage of some misfortune, the warrant of divine vengeance, the effect of witchcraft, &c. Lycosthenes used to go so far as to add to the description of each monster the picture of some calamity which was to be its sequel. To that opinion they owe their name, derived from the Latin verb *monstrare.*

Their ætiology was not less strange and incorrect. Rueff, in 1580, devoted a whole chapter to the inquiry, "An homines ex dæmonibus et rursus dæmones ex hominibus infantes concipere possunt?" and Casparus Schottus treated the subject in about the same style.†

They both give negative answers to the question, trusting to have proved by this means that monsters are not procreated by sexual intercourse of women with the devil. Other writers have endeavoured to explain the cause from copulation with brute animals, or with pregnant or menstruating women. Notwithstanding our more enlightened modern ideas on this subject, the origin of monstrous births remains still very mysterious. The opinions concerning it may be reduced to two main points: 1. To the original malformation of the germ; 2. To the subsequent deformation of the embryo by causes operating on its development.

I. *Original malformation of the germ.* — If, according to the opinions generally adopted at the present time, the germ may be considered as a product of secretion by the female organism, upon which the male sperm acts with its material and vital influence, we may suppose that this germ may be originally malformed, owing to some influence proceeding either from the female or from the male sex.

1. Such a primitive malformation of the germ seems to exist in those cases in which the same kind of monstrosity is repeatedly procreated by the same parents. The cause may be ascribed: —

a. To the mother. — It is a very important fact that, in such cases, various degrees of the same species of deformity are frequently produced in successive progression, so that the first born child is the most deformed; and in the following children the deformity progressively decreases, and finally disappears in the last born (G. Vrolik, Vering). Sometimes a deformity of the mother is communicated to her offspring; for instance, *congenital luxation of the femur.*

b. To the father. — Experience proves that a well-formed man may procreate with different women children with the same malformation (Meckel, Luber), and that a deformity of the father may be transmitted to the child (Burdach, Osiander). The last is however rare.

2. A second proof in support of the probability of an original malformation of the germ is found in hereditary deformities extending over more than one generation, viz. hare-lip, excessive number of fingers, *hypospadias*, &c.

3. A third proof may be deduced from the possibility that the ovarian ova in man and in the lower animals may be already malformed (Bischoff).

II. *Deformation of the originally well-formed germ.*— 1. It is said that this may be produced by mental impression of the pregnant woman, or what the German authors call *das Versehen.* But for this opinion no positive proof can be afforded. According to the observations published thereupon, and of which a great deal may be found in the learned article GENERATION of this *Cyclopædia*, all the supposed mental impressions, which have been considered as the cause of malformations, took place, with few exceptions, in the last stage of pregnancy.* And even in those cases in which an earlier period may be certified, we could object that the *post hoc* must not always lead to the conclusion *ergo propter hoc.* It is of some importance to appreciate the correctness of this

* From τέρας, monster; and λόγος, science.

† I. Rueffus de Conceptu et Generatione Hominis. Francof. ad M. 1580. P. Casparus Schottus e Societate Jesu, Physica curiosa, aucta et correcta, sive Mirabilia Naturæ et Artis. Lib. i. § xxii.

* See my publications in Tijdschrift v. Natuurlyke geschiedenis en Physiologie, d. iv. bl. 221, en tolgy. en Handb. d. Ziektch. Ontlurh. d. i. bl. 339.

reasoning, for the theory of the mental impressions, which was so readily adopted in the barbarous middle ages, as a mode of saving poor and innocent women from torture and stake, finds even in the present day more advocates than might have been expected. Of this I was convinced at the Congress of Naturalists at Aix-la-Chapelle in 1847, and in the Report of the Transactions of the *Schweizerischen Naturf. Gesellschaft zu Chur*, 29, 30, 31 Juli, 1844, in which the affected mind of the pregnant woman is said to produce a mysterious effect on the fœtus, and that the medium by which this influence is communicated may be the hearing as well as the sight! To crown all these absurdities, we see mentioned in Rust, *Magasin*, B. xxi. S. 261., that a woman gave birth to a child with imperfect bones, which is attributed to her having been present, *before her pregnancy*, at the execution of a criminal by breaking on the wheel. To all these fantastical considerations I oppose the following arguments: —

a. That malformations seldom, or perhaps never, agree with apprehensions or fears *à priori* of pregnant women (G. Vrolik, T. Zimmer, J. J. Plenck, and Burdach). On the contrary, it often happens that a woman who has once procreated a malformation, and is continually troubled by the fear of another similar sad occurrence, may become the happy mother of a second well-formed child.

b. That the fœtus, even when a germ, is quite independent; transferred from the ovary into the uterus, it needs for its developement a material intercourse with the maternal body, but no *organic* connection; for which reason it can be formed as well without as within the uterus, as in extra-uterine pregnancy; that it stands in no connection, either vascular or nervous, with the body of the mother, and that therefore it is improbable that her mental condition can have any influence whatever upon the form of the fœtus.

c. That malformations occur likewise among the inferior animals,—insects, testaceous animals, echinodermata,—in which the developement of psychical life is very imperfect, and the oviparous generation of which must preserve the young from the influence of disordered maternal imagination.

d. That in the case of twins, as the acephali specially show, one child may be malformed and the other in perfect condition, notwithstanding they were both exposed to the same influences.

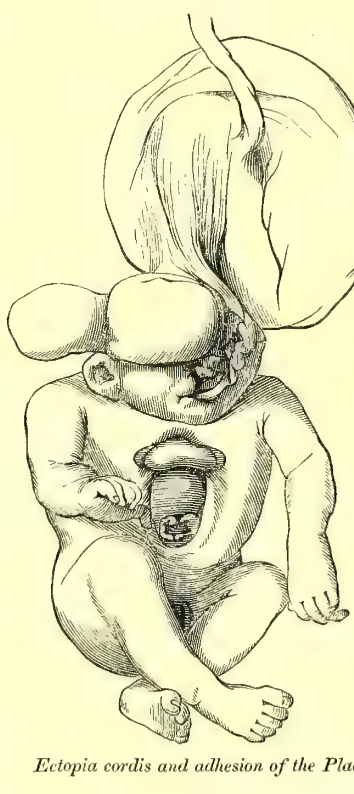
e. That more deeply situated organs, the very existence of which may be unknown to the pregnant woman, may be malformed; as for instance, the heart, the intestinal tube, &c.

If now, on all these grounds, I exclude the mental impressions of pregnant women from the ætiology of malformations, I do not mean to deny the influence which by her somatic condition the mother may exercise upon the fœtus. Thus, if in consequence of mental agitation, her body were to suffer a violent shock, this might have a prejudicial influence on the material transmission which takes place between her and the fœtus, and the latter might thereby become morbidly affected. There are instances of its being the subject of intermittent fever (P. Russell); of sudden death occasioned by frightful agitation of the mother (Wienholdt); of jaundice communicated by the mother (Kerckring); of small-pox (Jenner, Montgomery, Friedlander); of syphilis and scarlet fever (R. Lee), all derived from the mother. But all this is entirely different from the effect of mental impressions. It is a material result, easily conceived, and of which physiologists need no further explanation.

2. A second cause of malformation of the fœtus is sought in external injury suffered by women during their pregnancy. Meckel goes so far as to reject this entirely. In some deformities, for instance, in *hydrops ventriculorum cerebri*, the effect of external injury is easily proved.

3. A third cause is attributed to diseases of the ovum and of the fœtus. Simpson (Edinburgh Med. and Surg. Journal, No. 127., April, 1836, and Gazette Medicale de Paris, Nov. 1836, p. 393.) has described an acute and chronic form of placentitis, to which ought to be ascribed all those singular exudations which attach themselves to the fœtus as pseudo-membranes. *Fig*. 595. gives a specimen of adhesion of the placenta to the head of a fœtus deformed by *urania*.

Fig. 595.



Ectopia cordis and adhesion of the Placenta.

In *fig*. 596. a pseudo-membrane passes to the forehead, round which is twisted the umbilical cord.

Fig. 596.

In some, but very rare, cases, the coats of the ovum are destroyed, and the fœtus is immediately attached to the inner surface of the uterus (Steinmetz). It is not to be denied, that through these pseudo-membranes some malformations of the fœtus may be occasioned, as Montgomery has proved, such as the truncation of the extremities, which he names *self-amputation*. Further than this, however, we may not go, for the *brides placentaires* of Professor St. Hilaire are certainly not a universal cause of monstrosity. They are too accidental and unstable to be such. The existence of malformations in eggs which Geoffroy St. Hilaire coated over with varnish or wax, affords no proof of the possibility of a mechanical origin of monstrosities. The exclusion of the air prevents, in such a case, the necessary material change in the ovum, in consequence of which the perfect developement of the fœtus is impaired.

The morbid state of the coats of the ovum may likewise cause the so-called *molæ*, which, according to their consistency, are divided into *molæ fungosæ*, *carnosæ*, *cruentæ*, and *tendinosæ*. Valentin* distinguishes in the sanguineous mass of *mola carnosa* a net of vessels, from which the blood issues. It is the vascular net of the chorion, in which the mass of blood has been collected, in consequence of too great a supply from the uterus. By these means the villi are distended and removed. The ovum being thus degenerated, occasions defective respiration and nutrition of the fœtus, which in consequence soon dies. The ovum, however, may still continue to grow, and is finally expelled. In this manner these *molæ* are frequently the cause of miscarriage.

* Repert. Anat. u. Physiol., Berlin, 1837, B. i. S. 127.

Kerckring* inveighed in a spirited and ingenious manner against the strange accounts which were formerly given of these *molæ*.

To the diseases of the placenta are referred *enlargement* (Kyll, Pierrard, Devilliers), *congestion* and *apoplexy* (J. Clarke, Darigan), *calcareous concretions* (Hannover). For the ætiology of malformations, this pathological anatomy of the placenta is, however, very unproductive. None of these can be explained by it, nor were any accompanied by these placental diseases.

Nor does the nosology of the fœtus afford us much more information, notwithstanding the monograph given by J. Gmesser.† It cannot, however, be denied, that some of its diseases may give rise to deformities; for instance, chronic inflammation of the brain to *hydrops ventriculorum cerebri*, and this again to *Acrania*.

Perhaps also, as Rokitansky states, a morbid condition of the valves may be the cause of some congenital abnormities of the heart. Yet, notwithstanding all this, the diseases of the fœtus can only, in a very limited sense, be assigned as the cause of its malformation; and hence the opinion of Otto, who ascribes to this source a great many malformations, ought to be rejected.

4. A fourth, and assuredly very general, cause of malformation, consists in impeded developement of the fœtus by some remote and unknown cause. It is matter of dispute whether this deforming cause operates on the fœtus in its totality, or whether it affects originally only one system, which spreads its deforming influence over all the others. This last idea was embraced by Tiedemann, who at first deduced all monstrosities from some defect of the vascular, and later from the nervous system. In opposition to this hypothesis, I suggest the following considerations.

a. It is opposed to anatomical evidence. The *cyclopia*, whose nature consists in a more or less simplified eye and a displaced or absent external nose, is attributed by Tiedemann to the original absence of olfactory nerves, producing the deformation of the nasal cavity, and the original fusion of the optic nerves, and of the thalami nervorum opticorum effecting the simplification of the eye. I have found, however, in *cyclopes*, more than once, olfactory nerves, and have likewise seen that there was no constant concurrence between the simplified form of the eye and of the optic nerve. A double optic nerve may be found with a single eye-ball (Eller, Henermann). With complete duplication of the internal parts of the eye, and even with two separate eyes, I found a single optic nerve, and likewise a double, though not complete, as well as a single eye-ball, notwithstanding the entire absence of the optic nerve. Similar facts are quoted by Haller and G. F. Wolff. Hare-lip with cleft

* Specil. Anat. Amstelodami, 1670, Observ. 38 et 95.

† Die Krankheiten des Fœtus. Breslau, 1827. 8vo

palate is attributed by Tiedemann to the original absence of olfactory nerves. G. Vrolik found them, however, in children with hare-lip. The nerves of organs may exist, although the organs themselves may be absent (Seiler, W. Vrolik); and inversely, the nerves may be wanting, while the organs are present (C. G. Buttner). In *anencephali* the body is very massive, notwithstanding the imperfect condition of the nervous centres. In double monsters there is no definite correspondence between the condition of the nervous system and the duplication of the body (W. Vrolik).*

b. Embryogenesis teaches that the formation of the several parts of the body is not essentially the result of that of the nervous system, but that, on the contrary, each part is formed and developed independently. I refer to what I have already said, in 1836 (in my treatise on *Cyclopia*), and am happy to find J. Muller, Rathke, Bischoff, Burdach, and Stannius, with me on this subject.

What is now proved for the nervous system, may equally be applied to the system of blood-vessels; and hence I presume to conclude, that no malformation whatever proceeds from a central system, but is occasioned merely by impeded developement, the cause of which remains concealed. This impediment may be confined to one part, or may be extended over more. This extension may sometimes stand either in causal connexion with an original malformation, as for instance the displacing of the nose in *cyclopes*; or may take place in an entirely independent manner. In the latter case, it is a complication of malformation, which proves that it may extend itself to more than one region of the body, and to more than one apparatus. I have met with an instance of this, in which to *acrania*, *cyclopia*, and absence of the lower jaw, was added *ectopia* of the intestines. If the origin of the malformation is derived from impeded developement, the so-called *monstra per defectum* are the result, and from excessive formation arise the *monstra per excessum.*

The malformations occasioned by impeded developement may, for the most part, be compared with the natural forms through which the fœtus passes in its normal developement. On this is founded the ingenious idea of Meckel, previously suggested by Wolff, that most malformations are caused by arrest of developement (*bildungshemmung*), for which reason they must be said, according to Bischoff, to be *formed through arrested developement* (*hemmungsbildungen*). They, however, never give us a perfect representation of the form at which the fœtus has been arrested in its developement, because the increased growth and the progressive nutrition of the fœtus cannot but make an important modification therein. As the transient forms of the human fœtus are for the most part comparable to the persistent forms of the lower animals, the malformations occasioned by impeded developement often acquire a brute appearance; and thus a reason is at the same time given why they exhibit, in different animals, the form of the lower, but not of the higher classes.

A consequence of this mode of origin is, that they never deviate so much from the normal form as would exclude them from the rank of organized beings; and that the deviations from the natural form are confined within definite limits, so that they always reremind us more or less of the regular form. Fixed laws of organization prevail in them, by which they exhibit a certain fitness of organization, and a tendency to render the capacity for life as great as possible, notwithstanding the malformation. Peculiar vital relations are hereby produced adapting them for uterine life, and many are brought forth well nourished and at full time. Most, however, are unfit for life after birth, though for very different reasons.

The following remarks may serve for the elucidation of these peculiar vital accommodations: —

1. We never see in malformed births, dissimilar parts fused or united with each other, such as the intestinal tube with the aorta, the arteries with the nerves, &c. Each part, therefore, retains, to a certain degree, its own independence, according to what Fleischmann denominates *lex proprietatis.* The gullet sometimes coalesces with the larynx, and the bladder with the rectum; but these parts are not originally dissimilar, being developed from a common mass.

2. The malformed parts are restricted to their determinate place, according to what Fleischmann denominates *lex topicorum.*

3. No malformed organ loses entirely its own character, and no malformed animal loses its generic distinction. It is, therefore, justly observed by Sœmmering, that nature does not deviate *ad infinitum*, and that even in monstrosities a distinct gradation and natural order are observable.

An immediate consequence of this must be, that in one and the same sort of monstrosity, there are different degrees of malformation, varying from the greatest possible degree to the very least. We might thus consider the different monstrosities as so many genera, and their varieties as so many species, whereby, according to J. T. Meckel, a new organic kingdom is constituted, differing only from the others by less constancy of form. Consequently a definite type prevails in the generation of monstrosities, and they are subjected to fixed organic laws. This order appears even — 1. *In the number* in which they occur within a certain space of time. In 3000 births in Paris, there occurs about one monster (J. Geoffroy St. Hilaire). 2. *In the sex.* In impeded developement, the malformed children are more frequently female,

* On this subject I have given copious elucidation in the Treatise on Cyclopia in Transactions of the First Class of the Royal Netherland Institute, 1836, vol. v. p. 25.; on Double Monsters, *ibid.* 1840, vol. ix.; and Handbuch, vol. i. 1840.

in some sorts of double monsters, male. 3. *In a definite proportion between the species of the animals, and the most frequent monstrosities in them. Cyclopes*, for instance, especially with a snout, occur most frequently in swine; double monsters in man. 4. *In the constant form of monsters, even amongst the most heterogeneous animals. Cyclopia*, double monsters, *acrania*, have in Birds precisely the same characters as in the Mammalia. 5. *In the greater predisposition to monstrosity among some animals.* This is greater among domestic than among wild animals; greater among the more perfect, than among the less perfect; three-fourths of the monstrosities occur among Mammalia, one-fourth among Birds (J. Geoffroy St. Hilaire). They happen seldom among Reptilia, still less frequently among Fishes, Mollusca, Articulata, and Radiata.

From these premises the consequence is easily derived, that monstrosities do not take place by chance, and therefore do not by any means deserve the so very general appellation of caprices of nature (*lusus naturæ*). The result of this is, that they often present a quantitative antithesis, according to what Geoffroy St. Hilaire denominates *loi de balancement.* According to this law, the excessive developement of one part of the body is often connected with checked formation of another. To *anencephalia*, *cyclopia*, *spina bifida*, are often joined fingers and toes in excessive number; to *sireno-melia* superfluous vertebræ and ribs; and frequently there occur in double monsters malformations of the head. Meckel saw, in one single instance, this antithesis extend itself over different children of one and the same mother. A girl had on each extremity a superfluous digit, and one hand of her sister wanted four fingers, being the number of digits which her sister had in excess, reckoning the four extremities together.

I have now arrived to the classification of monstrosities; but in order to prevent all unnecessary waste of time, I shall avoid entering into a full critical examination of the systems propounded by Licetus, Huber, Wigtel, Malacarne, Buffon, Blumenbach, Breschet, Geoffroy St. Hilaire, Gurlt, Otto, and Bischoff. Concerning these I refer to Bischoff*, from whom Rokitansky has chiefly borrowed what he gives in his manual. According to my conviction, no suitable classification of monstrosities can be given, and the efforts employed to this end may be regarded as failures. I confine myself, therefore, to a simple *grouping*, taking embryogenesis as my basis, without presuming on any further classification, and I thus avoid a barbarous nomenclature, which, in my opinion, is attended with no advantage. My object is simply to make the doctrine of malformations useful for physiology and for medical practice, nearly in the same manner as was done, almost simultaneously with me, by the excellent F. A. von Ammon.*

* Entwickelungs Geschichte mit besondere Berücksichtigung der Missbildungen, in R. Wagner Handwörterbuch d. Physiologie, B. i. S. 887.

Malformations of the Ovum.

1. *Mola botryoides* or *hydatica*, — *Hydrometra aquatica*,—is a degeneration of the chorion into vesicles of different sizes, filled with a serous liquor, which were erroneously taken for hydatids. They cover the surface of the enlarged ovum, and are the villi of the chorion, which, as no formation of vessels took place, retained their original vesicular form (Ruysch, Albinus, Sandifort, Cruveilhier, Velpeau). Sometimes a fœtus is found in it, which, however, in relation to the ovum may be said to be small.

The small embryo most probably dies in the early period of pregnancy, and the degenerated ovum continues to grow till a later period, when it is evacuated. In most cases abortion is the consequence of this condition of the ovum. Sometimes, nevertheless, the pregnancy lasts till the full time (Gregorini), or sometimes longer, as happened in a case observed by Lossius, in which it lasted six years. Sometimes the fœtus disappears, and then this degenerated vesicular mass is evacuated alone, with excessive hæmorrhage and great pain. This is the last period of what is called *false pregnancy.*

The vesicles are inclosed in a kind of decidua; they are fixed on pedicles, from which arise other vesicles with smaller stems, so as to give to the whole the appearance of the chorion, in an earlier period of its existence, when the villi still preserve their original vesicular form. The accurate observations of Boeck show that, in most cases, these vesicles contain blood, which sometimes can be displaced by pressure from the one to the other vesicle, or is coagulated. The internal surface of the membrane which forms the vesicle is smooth, the external interwoven with fibres. A thus degenerated ovum has not the power of bringing the fœtus to a state of perfect maturity. The death of the fœtus and miscarriage are its consequences. Sometimes the *Mola botryoides* is accompanied by malformation of the fœtus (Valisnieri).

From this degeneration ought to be distinguished: 1st. The vesicular degeneration of the placenta, when retained after a natural parturition in the womb (Gregorini); 2nd. The *Polypi fugaces* or *vesiculares* evacuated in the anni climacterici by elderly women (Levret); 3rd. Those after suppressed menstruation in unpregnant women (Schleierbach, Watson, Sporing, Lisfranc). As I have no observations of my own of any of these cases, I dare not pronounce any opinion about the affinity of these vesicles to the *Mola botryoides.*

2. *Separation of the placenta into lobes or cotyledons.* — This is without doubt to be attributed to an arrest at a lower degree of developement, and it offers some resemblance

* Die angeborenen Chirurgischen Krankheiten des Menschen. Berlin, 1842.

to the placenta of the Ruminants. The smallest amount of deviation is a division into two coherent lobes, which are separated only by a small constriction (J. F. Meckel, Ebert). Such a placenta has an oblong form. Sometimes there is a single lobe adjoined to the placenta (*placenta succenturiata*); it is of much smaller dimensions than the placenta itself, and united to it by vessels, without a cord. The placenta may also be divided into three (Rohault, Schwencke), four (Hoboken), five (Meckel), or seven lobes (Kerckring, Wrisberg). In the observation of Kerckring, the arrest at a lower stage of development is clearly shown by the presence of the *Vena omphalo-mesenterica*.

3. *The vessels of the umbilical cord are separated* near the placenta, and meet at a considerable distance from it (Sandifort, Wrisberg, Adolph). In one of the published cases, this disposition of the vessels was the cause of their rupture, which produced the child's death by hæmorrhage. Sometimes they were observed to run separately from the placenta to the abdomen of the fœtus, into which they penetrated through separate openings. In most cases they meet each other just at the umbilicus (Gavel, Van Solingen).

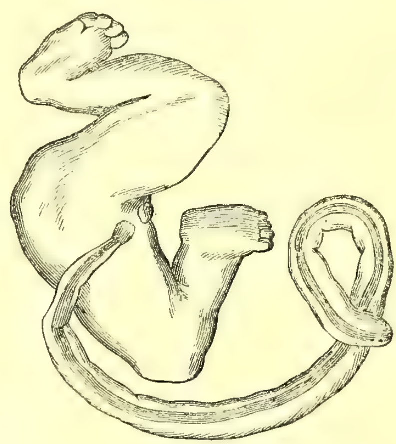
Fig. 597.

Malformed Fœtus, showing the cord entwined around the neck and part of the body.

4. *The umbilical cord too long.*—The common length of the cord is twenty inches (Roederer, Wrisberg), but it may be forty-eight inches (Wrisberg), sometimes even five feet (Morlanne). The usual effect of such an abnormal length of the cord is a circumvolution of it round the body of the fœtus. An example of it is given in a very misformed fœtus in *fig.* 597.

A circumvolution of this kind may sometimes become dangerous: 1. By acting as a ligature round the neck, and producing strangulation of the fœtus (Buchanan, Hebenstreit); 2. By constricting one of the extremities, and producing the *spontaneous amputation* of Montgomery (Art. Fœtus, *fig.* 157. Vol. II.) 3. By forming single or compound knots. Although these are in general not dangerous, while the vessels are sufficiently protected against pressure by the Whartonian gelatine, they may nevertheless in some cases be drawn so tight as to obstruct the communication between mother and child (Sandifort, Irvets, D. W. H. Busch); and sometimes the umbilical cord breaks off near the knot when the vessels have become obliterated by the pressure. *Fig.* 598. gives an example of this in an acephalus.

Fig. 598.



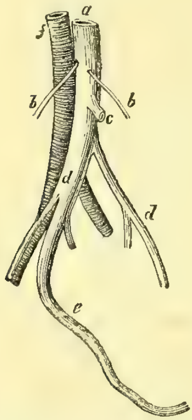
(*After Bonn.*)

5. *The umbilical cord too short.*—Wrisberg gives as a minimum a measure of seven inches. It may, however, be much less. This shortness of the cord is in general accompanied by a deformity of the fœtus, usually by *ectopia* of the abdominal viscera, by which it indicates an arrest of developement at an earlier period of embryogenesis. In this way we should interpret the accounts of absence of the umbilical cord.

6. *Absence of one of the umbilical arteries*, is even observed in double monsters, but occurs principally in *ectopia viscerum abdomi-*

nalium, and in defective formation of the inferior part of the body. Serres hence derived the conclusion, that this malformation is the consequence of the want of one of the umbilical arteries; which is however wrong, as the evolution of the whole body may be complete, even when one of the umbilical arteries is wanting. *Fig.* 599. represents a specimen of this kind.

Fig. 599.



a, aorta; *b*, *b*, spermatic arteries; *c*, superior mesenteric; *d*, *d*, common iliacs; *e*, the single umbilical artery; *f*, vena cava.

Mende even observed in a very well formed child absence of one of the umbilical arteries, together with an unusual course of the umbilical vein, which, instead of communicating with the vena portæ, opened immediately into the right auricle of the heart.

7. *Increased number of the vessels of the cord.* — A double umbilical vein is constantly to be found in the Quadrumana of the New World (Rudolphi). In Man the unusual plurality of the umbilical vessels is but apparent, as it is produced by the persistence of the *vasa omphalo-mesenterica.*

8. *Persistence of the umbilical vesicle*, is a natural condition in the *Ouistiti* (Rudolphi), and occurs as a deviation in Man. Sometimes it is only its duct that remains united with the small intestine, forming what we call a *diverticulum.*

9. *Constriction of the umbilical cord* occurs at the point where the cord penetrates into the abdomen. In the constricted part the vessels, although remarkably narrowed, still allow in some measure the circulation of the blood. The cord is thereby contorted into a spiral. The death of the fœtus is its usual effect (Landsberger). *Fig.* 147. of the second volume of this Cyclopædia gives a representation of this constriction of the umbilical cord.

10. *The umbilical cord too thick.* — Its diameter varies from $1\frac{1}{2}$—$2\frac{1}{2}$ inches. This is, in general, the consequence of an uncommon accumulation of the Whartonian gelatine, or of an œdematous conditon. In one of the recorded cases, the superior extremities were wanting, and the anus was closed. In other cases it is occasioned by an enormous quantity of the liquor amnii, which is usually accompanied with an abnormal developement or impeded growth of the fœtus.

Malformations of the Fœtus.

It is impossible to give in a concise article, such as is suited to a cyclopædia, a complete description of all the various malformations of the fœtus. I must refer to my manual, published in Dutch, under the title *De menschelyke Vrucht beschouwd in hare regelmatige en onregelmatige ontwikkeling*, Amsterdam, 1840 en 1842, and to my *Tabulæ ad illustrandam Embryo-genesin Hominis et Mammalium*, where a more full and accurate description of the various kinds of malformations of the fœtus is to be found. I can give here only a short description of the principal groups, as an introduction to the doctrine of the malformations of the fœtus.

A. Monstrosities produced by an Arrest of Developement.

I. *Non-closure of the anterior Part of the Body.*

Embryogenesis teaches us, that the thoracic and abdominal cavities are originally open, and close themselves by degrees at a later period of uterine life. The late ossification of the sternum and of the pubic bones is the result of this original disposition. The points of ossification are not formed in the broad cartilaginous basis of the sternum before the fourth or fifth month of pregnancy; they are in the beginning widely separated from each other by broad intervals in the middle, and approach later to fuse into one central osseous piece. This mode of formation explains some of the original malformations of the sternum; namely, its abnormal breadth, the openings which are found in it, and its separation into two parts. These two last conditions denote, that the sternum is the compound of two lateral halves fused together (Rathke). The separation of the sternum into two parts usually accompanies *ectopia* of the thoracic and abdominal viscera.

Sometimes, although the thoracic viscera are enclosed in their cavity, the original division of the sternum remains, and is covered up by the skin (Ficker, Serres, Winslow). In some rare cases, the whole or the largest part of the sternum is absent in individuals with no other deformity (Von Ammon). In most of these cases the manubrium alone is present (Wiedemann). In some, but very rare, cases the anterior wall of the thoracic and abdominal cavity is only closed by the skin, and its osseous and fleshy parts are completely deficient (R. G. Mayne). The linea alba is, as well as the sternum, the cicatrix of a cleft existing at an earlier period. This explains its abnormal breadth, obvious in those cases in which the wall of the abdomen has been closed at a later period than usual. An example of it is given in my Tabula XXIV. *fig.* 4. Sometimes the muscles of the anterior abdominal wall are wanting, in which case the convolutions of the intestines may be seen and felt through the skin (Von Ammon). The thoracic and abdominal cavities being open in the first periods of embryogenesis, if this condition persists abnormally, it produces *ectopia of the thoracic and abdominal viscera.* The aperture through which the *ectopia* takes place has a constant tendency to close; it shrinks therefore sometimes to a very small opening (Hammer). Sometimes it is closed in the middle, by a band which separates the uncovered viscera into two portions (Hühner, Wolff).

Its principal forms are: —

1. *Fissure of the whole anterior Wall of the Body.*

a. Complete ectopia of the thoracic and abdominal viscera, which lie bare upon the anterior surface of the body, to which is generally added a cloaca. (*Fig.* 600.)

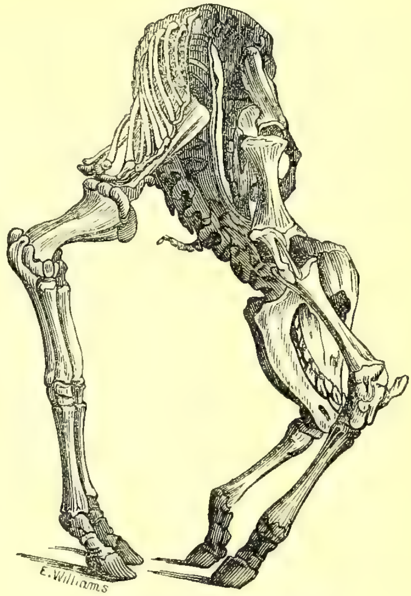
Fig. 600.

Child with ectopia viscerum.

a, liver; *b*, heart; *c*, *c*, lung; *d*, stomach; *e*, spleen; *f*, *f*, intestinal canal; *g*, kidney; *h*, chorion; *i*, amnion; *k*, umbilical cord; *m*, placenta.

The skeleton is very imperfect, in this complete ectopia; the thorax open, and the vertebral column misformed by *scoliosis.* — This may produce, as often met with in calves, a complete inversion of the body, so that through distortion of the spine, the head is placed between the hind feet. This is what Gurlt calls *schistozomus reflexus*, and what I represent in *fig.* 601.

Fig. 601.



Schistozomus reflexus (Gurlt).

2. *Fissure of the Thorax.*

Ectopia of the heart. — In the regular evolution of the fœtus, the opening on the anterior wall of the body closes itself, first at its superior part, so as to cover the thoracic viscera, while a part of the abdominal intestines still remain out of their cavity and in the sheath of the umbilical cord. Thus the thoracic cavity is in general already closed, whilst the abdominal is yet open. Nevertheless, it sometimes happens that the abdominal cavity is completed, and that its viscera are perfectly enclosed, whilst the thorax remains open, and the heart is placed on its anterior surface. In this malformation, called *ectopia cordis*, the heart has no pericardium, and is situated on the median line of the anterior wall of the thorax; it is more or less rounded, and in general well formed, as may be seen in *fig.* 595. The sternum is wanting (Tournelle, Norand, Sandifort); divided into two parts (Buttner, Martinez); or formed only by the manubrium (Manchardt). It is rarely complete; but this is often the case when the heart protrudes at the neck (Muse, Bubonnais, Breschet), or in the epigastric region (Wilson).

During fœtal life, the ectopia of the heart is immaterial, but soon after birth it causes the death of the child. Cruveilhier published some interesting observations on the movements of the heart in a case in which life was protracted for a longer time than usual.*

* British and Foreign Review, No. XXVI. October, 1841, p. 533.

3. *Fissure of the anterior abdominal Wall.*

a. Complete ectopia of the abdominal viscera.—The abdominal cavity is in general the last closed. When it alone remains open, the abdominal viscera only lie out of the body. The fissure is mostly extended from the ensiform process of the sternum to the pubic bones. One of the umbilical arteries is in general wanting. Commonly this malformation is complicated with adhesion of the membranes of the ovum or of the placenta to the divided integuments of the abdomen, with a cloaca, with defective generative or uropoietic organs, and with an incomplete pubic articulation.

b. Congenital umbilical hernia. — In a less degree of deformity, the fissure is limited to the epigastric region, above the insertion of the umbilical cord, because this part of the abdomen remains longest open. This gives origin to *congenital umbilical hernia.* — The umbilical cord passes under the viscera, which lie exposed, or are only covered by the peritoneum. In the last case a sort of hernial sac is formed, which has a cylindrical or globular form, and is produced by the two coats of the ovum.

The external coat is that part of the amnion which is the covering of the umbilical cord; the internal, the peritoneum, which is considered by Meckel as a continuation of the chorion from the umbilical cord. All these facts prove that *congenital umbilical hernia* is caused by an arrest of developement at that stage, in which a part of the abdominal viscera are contained in the sheath of the umbilical cord. The size of the tumor is variously modified by the number and by the volume of the viscera contained in it. When it contains the liver, it is of a bluish colour. The viscera lying in it, are always in an imperfect condition. Only four cases are known, in which the life of the malformed child lasted for any time after birth (Meckel, Cruveilhier, Ribke, Van der Voort); in the case of Van der Voort for eight, in that of Ribke for twelve months. In all these cases the external coat of the hernial sac has mortified, and the tumor has become gradually covered by the skin. An accurate diagnosis of this malformation is of great value. In two cases, in which it was not accurately recognised, a ligature was put round the tumor, and it was cut off. One of these cases was the subject of an interesting law proceeding.

c. Congenital ventral hernia. — The abdominal cavity may also remain open, below the umbilical cord (Fried, Hasenest, Bouchard). This produces congenital ventral hernia. The viscera lie exposed, or are covered by the peritoneum.

d. Acquired umbilical hernia. — Hernia in the umbilical cicatrix ought to be distinguished from all these forms of *ectopia.* It is not a congenital deformity, but is produced after birth by an expansion of the umbilical cicatrix to a globular, a cylindrical, or a conical tumor. It is often observed in adults. If we adopt for these the name of acquired, and for those of new-born children that of congenital hernia, it would be better to give to the true congenital umbilical hernia the name of *hernia funiculi umbilicalis* (Seiler).

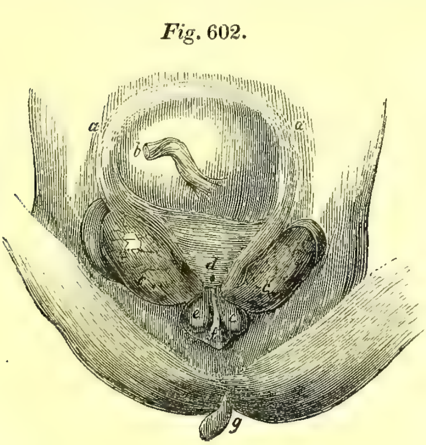
4. *Fissure of the pubic and hypogastric Regions.*

It sometimes happens that the pubic region alone remains open. For a correct idea of the malformations produced by it, it should be borne in mind that in the Mammalia, and, as recent observations teach, also in Man (Bischoff, Wagner, A. Thompson, Coste, Sevres, Arnold), the urinary bladder is formed by the allantois. This is originally in communication with the inferior part of the intestinal canal, so as to form for both a common outlet, called a cloaca, from which are evolved at a later period the peripheral openings of the intestinal tube, and of the uropoietic and generative organs. The pubic bones are formed later than the iliac (Meckel) and the previously existing ischiatic bones. Their formation proceeds from the outside to the inside; therefore they are at first separated from each other by a large interval, and subsequently approach each other, in a gradual manner, for the formation of an amphiarthrosis. The fœtus may be arrested at this period of incomplete pubic articulation. In an observation of Walter, there was a fissure in the pubic region, though the genital and uropoietic organs were not malformed. This is the normal condition of some mammalia, and of the majority of birds. An arrest of developement may also take place at the period when there exists a fusion between the rectum and the allantois. Of this various forms occur.

a. Formation of a cloaca.— A *cloaca* is said to exist, when the generative and urinary organs and the rectum have a common outlet. This is often complicated with *ectopia* of the thoracic and abdominal viscera. The cloaca may also exist alone. In its highest degree, the ureters, the imperfect organs of generation, and the opening of the rectum, are situated close to each other in a circular depression (Petit). In other cases, which approach more to the natural condition, there is a primordial urinary bladder, formed of two separate parts (Mery), or merely constituted by its bare posterior wall. *Fig.* 602. shows how the fissured urinary bladder may be complicated with the formation of a cloaca.

In most of the cases which I have published, the opening through which the fæces are evacuated, is formed by the ileum, and the rectum is closed or wanting. This confirms the original formation of the intestinal tube by a *mouth-* and *anus-gut.* In a case mentioned by Jung these two portions are quite separate, and have each its separate opening on the prolapsed posterior wall of the urinary bladder. When these two openings are fused, the cloaca persists, but approaches more to the natural condition. This may take place in different ways:— 1. The orifices of the ureters only may be found on the posterior wall of the bladder, or in the so-called inverted bladder, while the rectum still coheres with the genital organs, just as in the cases of imperforate anus just mentioned (Meckel, Burns), or with an open anus, as in the cases of Zhryham, Oliver, and Bonnet; this condition approaches the nearest to the natural state,

Fig. 602.



Hypogastric region of a Child, which lived twenty-two days, with vesica inversa, &c.

a, a, congenital umbilical hernia; *b,* umbilical cord; *c, c,* the separated halves of the vesica urinaria, with the urethral orifices; *d,* anus; *e, e,* penis epispadiacus; *f,* frenulum; *g,* cutaneous appendage to the closed anus.

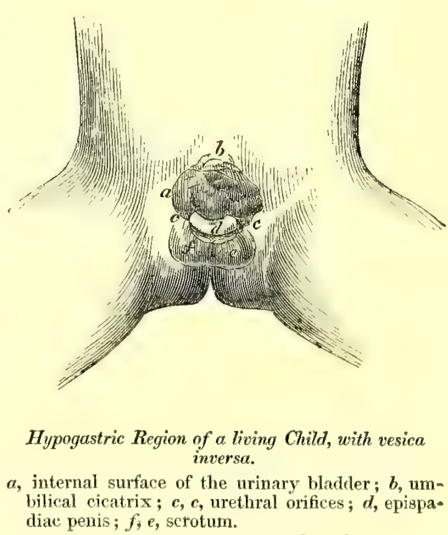
if the urinary bladder is complete (Martin); 2. The rectum may be separate, while the urinary bladder remains fissured and fused with the genital organs (Meckel, Gross); 3. The fissured urinary bladder may be separated from the anus, without taking up the ureters, which then open themselves into the rectum (Meckel, Oberteuffer). In some cases the outlets of these three apparatus are found not on a flat surface, but in a cavity. The cloaca, existing previously on the surface of the body, is then removed from it and folded in, so as to form a cavity.

In another degree of malformation the cavity is formed, and the uropoietic and generative organs are completely separated from each other; but the rectum, being a distinct organ, is nevertheless in connection with one of the said parts, by means of a sort of canal. In the female sex this communication is found between the rectum and vagina (*fistula ani vaginalis congenita*); in the male sex between the rectum and urinary bladder (*fistula ani vesicalis congenita*). The transition towards the natural state is nearest when the rectum opens into the urethra; to this condition, when it is complicated with an imperforate anus, Papendorp has given the name of *atresia ani urethralis.*

b. Congenital fissure of the urinary bladder.— Without a cloaca, and with a perforate anus, the interior surface of the posterior part of the bladder may lie exposed on the hypogastric region (*prolapsus, inversio, fissio vesicæ*). It then forms a red, spongy tumor, situated somewhat above the separated pubic bones, and involving the umbilicus, so as to give the appearance of a deficiency of the umbilical cicatrix. In male children the orifices of the vasa deferentia are to be found on the inferior part of the tumor. The urethral orifices are papillary eminences on the naked internal surface of the bladder. The urine drops continually out of them, but may sometimes be seen to issue in a small stream. The pubic bones are widely apart, sometimes with an interspace of four inches. They have no intermediate cartilage, but are merely united together by a ligament, without forming a synchondrosis. The consequence of this is a very peculiar reeling in the walk of the malformed subject, and a great disposition to inguinal hernia, due to the absence of sufficient support at the interior surface of the body. The penis is fissured on its superior surface (*epispadias*). The testes are, even in adults, very small, and often retained in the abdomen or in the inguinal canals. The seminal vesicles, the prostate and the vasa deferentia, offer various deviations. In the female sex the labia majora and minora are separated and without a commissure at their upper part. The vagina is often closed or very narrow. The anus is more protruded than in the natural condition.

Sometimes the penis is epispadiac, with a well-formed urinary bladder. In such a case, Bonn found, nevertheless, the pubic bones apart, but united by a ligamentous texture. Although the continual dropping of the urine is a very annoying disturbance, which I contrived to remove by the means illustrated in *figs.* 603 and 604, and although the generative organs are very incomplete, this malformation is not dangerous to life, which in several cases has been remarkably protracted.

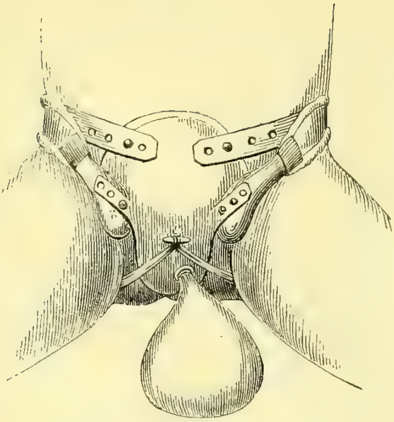
Fig. 603.



Hypogastric Region of a living Child, with vesica inversa.

a, internal surface of the urinary bladder; *b,* umbilical cicatrix; *c, c,* urethral orifices; *d,* epispadiac penis; *f, e,* scrotum.

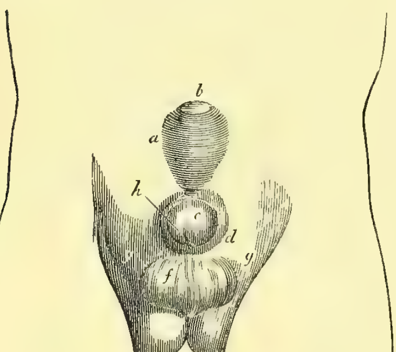
Fig. 604.



The same Region armed with an Apparatus for the reception and evacuation of Urine.

c. Ectopia vesicæ urinariæ. — The smallest degree of deformity is when the urinary bladder remains intact, but lies in an opening in the wall of the hypogastric region. It is *ectopia vesicæ urinariæ*, of which a representation is given in *fig.* 605.; and for more details I refer to my "Tabulæ ad illustrandum embryogenesin," etc., Tab. xxx.

Fig. 605.



Hypogastric Region of a Child, which lived six years, with ectopia vesicæ urinariæ.

a, part of the bladder lying on the surface of the abdomen; *b*, umbilical cicatrix; *c*, penis; *d*,*d*, prepuce; *h*, urethral orifice; *f*, scrotum; *g*,*g*, testes, lying at the inguinal region.

d. Inversio vesicæ uninariæ. Prolapsus vesicæ urinariæ inversæ.—If the urachus remains open after birth, the urinary bladder may be expelled, and thereby inverted through it. R. Froriep (*Chirurg. Kupfertafeln*, Heft 67. Taf. cccxl.) has given an example of this malformation. It ought to be distinguished from the inversion of the bladder through the urethra, which is possible even in adult women (Voigtel).

If we take a general survey of all these cases of non-closure of the hypogastric region, it is evident that they are intimately connected with one another.

The cloacal disposition is the highest, the *ectopia* of the urinary bladder the lowest, degree of malformation, and therefore the latter is a distinct transition towards the natural condition. The inversion of the urinary bladder observed by Froriep has, as to its origin, no direct relation to the other forms. It is but an accidental effect of the remaining open of the urachus, through which the bladder chanced to become inverted, and the urine flowed away through the urethra if the child was held upright. From the gradual transition of one form into the other, I conclude that the origin of this malformation cannot well be attributed to a mechanical cause, as Duncan and Bonn have asserted nearly at the same time. They both consider it the effect of a preternatural accumulation of urine, causing a violent distension, and later a rupture of the bladder, of the urethra, of the hypogastric region, and of the pubic articulation. This theory had already, in the year 1816, a very strong opponent in my father (Verh. d. 1[e] kl. van het Koninkl. Nederl. Instit. D. II. B. 88). His chief arguments against it, to which I add my own, are:

1. That, if the urinary bladder bursts, as may happen in adults, the urine will be evacuated into the abdominal cavity, without fissuring the anterior wall. 2. That it is improbable that in some cases such an accumulation should fissure the whole apparatus, and in others restrict its effect to the corpora cavernosa, penis, and the urethra, as may be seen in simple *epispadias* (W. Vrolik, Bosson, Salsmann, Morgagni, and Oberteuffer). 3. That by an observation of Baillie is proved, that in fissure of the urinary bladder the posterior part of the urethra may remain intact and closed, while the corpora cavernosa are fissured at the anterior part of the penis. 4. That I have often found in the fœtus *atresia urethræ* complicated with an unusual expansion of the urinary bladder and of the ureters, but without the least sign of bursting or of producing the malformation in question. 5. That *ectopia* of the urinary bladder demonstrates that the anterior wall of the abdomen may be open, the urinary bladder remaining intact; or the supposed effect may exist, when the cause is absent. From all these and other remarks and observations I conclude that the origin of this malformation is not to be found in a mechanical cause, neither internal nor external (Roose). I am much more inclined to ascribe all its different forms to arrest of developement. My chief grounds for this opinion are the frequent coexistence of:—1. The want of *arteriæ hypogastricæ* (G. Vrolik); 2. Abnormal condition of the kidneys and the ureters (Pinel, Cooper, Isenflamm); 3. Fissured dorsal vertebræ (Littre, Revolat, Delfin, G. Vrolik); and many other malformations, as *labium leporinum* (Dupuytren, Meckel), confluent toes (Saxtorph). The only question which remains is, what is the cause of this imperfect developement? As to the cloacal

formation, it is certain that it may be said to be an arrest at an earlier period of evolution; but this is not certain with regard to the *vesica fissa*. The origin of this can only be explained by an imperfect developement of the urinary bladder from the allantois. It is not improbable, as my drawing of the cloacal formation shows also, that the urinary bladder is formed by two half-parts, which approach each other anteriorly and posteriorly on the mesial line. If this junction does not occur, the different forms of vesica inversa will be formed. *Atresia ani* is, in the cloacal disposition, without doubt, an arrest of developement at an early period of embryogenesis; for previously the anus is closed. And *epispadias* shows that the penis is formed by two parts, which may remain separated from each other on the superior surface. Consequently it appears, that the name of *vesica inversa* is as improper as that of *vesica fissa.* But I shall propose no other name, because we know sufficiently the meaning of it.

5. *Cervical Fissure* (*Fistula colli congenita*).

Recent observations teach us that the original branchial fissures may persist in the neck even in adults. Hyrtl mentioned this malformation in a man of twenty, in whom the external cervical opening was small and communicated with the pharynx close to the epiglottis. Among 34,000 young men, Riecke found a *fistula colli congenita* twice.

6. *Fissure of the Face.*

In order to obtain a correct notion of the different forms under which fissure of the face may occur, it will be necessary to know the gradual metamorphoses of the face during its developement. Originally there is a common oral and nasal cavity. The place of the nose is occupied by two fissures, which extend from the internal angles of the eyes to the superior margin of the oral cavity. There is at this period not the least indication of a palate, so that the mouth and the nose form one common cavity. In a human fœtus of less than an inch in length, Meckel found the first rudiment of a palate, in the form of an arc or a horse-shoe shape. On each side this arc is gradually completed, so as to be at first open at its posterior part, but closed afterwards, and forming a complete transverse plate, separating the nasal from the oral cavity. Rathke examined this more in detail, in fœtuses of the sheep: —

1. He learned that the supermaxillary cavity is formed on each side from the lateral walls of the cranium.

2. That between those two parts grows out of the frontal wall of the skull a third eminence, which forms the basis for the septum of the nose, that is, for the formation of the vomer, of the septum of the ethmoid bone, and of the intermaxillary bones.

3. That the two parts, quoted under No. 1., are bent inwards, and coalesce with the mesial part.

4. That the nasal cavity is at first a groove, and has originally a form which persists through their whole life in fishes.

5. That the oral and the nasal cavity form originally a common cavity.

6. That the palate is originally a fissure. By arrest of developement in these different stages of embryogenesis, are formed the different species of facial fissure.

a. *Complete fissure of the face.* — The highest degree of malformation is, when the fissure is extended from the angle of the mouth to the internal angle of the eye, the orbits, the nose, and the mouth forming but one cavity. J. S. Meckel, Van Doeveren, and myself have published examples of this malformation complicated with *acrania*. The fissure sometimes extends only over one lateral part of the face (Leuckart), and in the greatest transition to the natural condition it is but a shallow groove, as is represented in *fig.* 596.

A fissure sometimes extends in a transverse direction over the head. C. Meyer observed this twice in new-born sheep. In both the palate had a double fissure, and the normal opening of the mouth reached as far as the ear, which in one of these lambs presented a transverse fissure.

b. *Double labium leporinum.* — A transition to the normal condition, yet a very imperfect one, is when the fissure is not extended over the whole surface of the face, but is restricted to the upper jaw. The highest degree of deformity is *double hare-lip with fissured palate* (*Labium leporinum duplex cum palato fisso*). On each side of the upper lip a fissure extends from the angles of the mouth to the *alæ nasi.* Between these is a protuberant tubercle, covered by a separate part of the upper lip, and consequently by the external skin and the gums. The tubercle is connected with the septum of the nose, generally obliquely distorted, and is filled up with the germs of the incisors. By the confusion of the oral and nasal cavities, the true nasal orifices are wanting, the osseous palate is defective, the soft palate and the uvula are fissured, and the vomer united anteriorly with the protuberance, hangs in the midst of the fissure. In a lesser degree of malformation, the alveolar margin of the upper jaw is alone fissured, and in the least degree the palate is complete.

c. *Single hare-lip.* — This name is adopted for the malformation when it is limited to one lateral part of the face. It may be complicated with fissured palate. The lip is then, on one side, fissured to the nostril, so as to form there an immediate communication between the oral and nasal cavity. The direction of the fissure is seldom accurately in the mesial line. If this occurs, it is the result of defective intermaxillary bones. The palate offers either a simple or a double fissure. In a less degree of malformation only the alveolar ridge is cleft, and, in the least, the palate is complete. In such a case the fissure of the upper lip is merely a small incision.

d. *Fissure of the palate without a hare-lip.* — The alveolar margin is in this case quite complete, but the palatine and the supermaxillary bones are largely separated from each other posteriorly, so as to form a fissure, more or less extensive, of the bony and of the soft palate. Sometimes there is only a fissure of the uvula (Von Ammon). The nearest approach to the natural state is, when the planes of the palatine bones form with each other an acute angle rising high upwards in the nasal cavity (Himly, W. Vrolik). In some cases, the palate is fissured at its anterior part, close to the *foramen palatinum anticum* (*hiatus foraminis palatini antici*, Von Ammon). *En resumé*, it appears that fissure of the palate and hare-lip are independent of each other. But it may happen that, originally, the fissure of the palate coexists with the hare-lip and closes itself later. The indentation which is observed in hare-lip without fissure of the palate, between the external incisive and the canine tooth, makes it probable that nature proceeds in this manner. It is also not improbable that hare-lip may sometimes be cured spontaneously in the womb. The gradual transition of the various forms of this malformation into each other, shows that its cause is not external and accidental, and that it is produced, neither by blows which the child inflicts upon itself with its fists (Jourdain), nor by a mechanical impediment preventing the union of the palatine laminæ (Pinnder). Complete fissure of the face and the palate is rather to be considered as an arrest of developement at an early period of formation. Hare-lip conforms with the fœtal condition in that period of developement which I have called the third. If the original intermediate protuberance does not unite itself with the lateral parts, double hare-lip is formed. The protuberance obvious in it is formed by the intermaxillary bone either in its totality, or only by a part of it. If it unites itself with only one lateral part, single hare-lip is formed. The intermaxillary bone is composed of four separate parts, of which each contains an alveolus. The result of this is, that each of these parts may be united, separately, with the supermaxillary bones ; which fact explains clearly why only three or two incisive teeth are sometimes to be found in the protuberance. The fissure of the upper lip sometimes occupies the mesial line, passing through the middle of the intermaxillary bone. This is also the case when the intermaxillary bone is wanting.

In this way, all the various forms of fissure of the face can be reduced to an arrest of developement, which explains in the meantime the constant tendency of the fissure to close itself, as may be observed in children having this malformation. Fissure of the palate and lip does not endanger the life of children, and union of the separated parts in hare-lip and cleft palate can be obtained by a surgical operation.

e. *Fissure of the under lip.* — The under lip is very seldom cleft (J. F. Meckel, Von Ammon, Nicati, Bonisson). It is equally rare for the under jaw to remain after birth separated into two parts.

II. *Fissure of the Skull* (*Acrania*).

Many forms of this monstrosity are known, to which different names have been given, as *acephalia spuria*, *microcephalia*, *anencephalia*, *hemicephalia*. But, for its shortness and etymological sense, I prefer the name of *acrania*, which was introduced by J. F. Meckel. Under this name I comprehend all the different forms in which this malformation occurs, and also, with Himly, the *hernia cerebri*. According to my opinion, the division into different families and genera, and the nomenclature of J. Geoffroy St. Hilaire, ought to be rejected. I, for my part, am always inclined to simplify science as much as possible, and to be succinct in its exposition; and I propose, therefore, the following types.

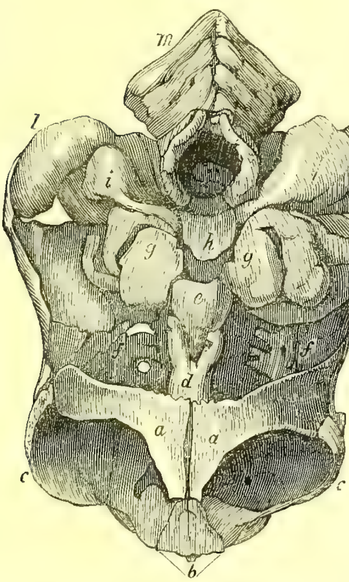
First Type. — *Want of the brain, and exposure of the whole basis of the skull.* — The superior surface of the cranium is flat, and not formed by the bones of the skull, but only by a membrane, of which the margin is very unequal, hard, and formed by bones. The external integuments extend over this margin, and terminate there in an unequal line, which is distinctly circumscribed by the thick hair of the head. With this cutaneous border is connected the slightly vaulted membrane, of a red, somewhat bloody colour, which immediately covers the periosteum that invests the more or less convex surface of the basis of the skull. The brain is wanting, but the central terminations of the cerebral nerves are in most cases present, yet sometimes these also are wanting (J. F. Meckel). The forehead is flat, and directed forwards in an oblique direction. The eyes protrude on its anterior or orbital margin, covered with swollen superior eyelids, and directed more or less upwards. The face is flat, and nearly horizontal ; the upper, and still more so the under jaw are comparatively longer than those of a well-formed subject ; the tongue is in general prominent, because the mouth cannot be shut on account of the

Fig. 606.

length of the under jaw. These distortions give to such monstrosities a certain brute-like aspect which induced the Germans to call them *Katzenkopfe* and the French *têtes de crapaud*. If the cervical part of the spinal column is in the meantime cleft, the cervix is so shortened, that the head seems to be fixed on the shoulders, and the chin rests on the breast, as is represented in *fig.* 606.

The malformation of the bones of the skull and of the face is very great; but as its description would take too much room here, I refer the reader to my *handbook* and my plates, and also to *fig.* 607., which will give a clear idea of it.

Fig. 607.



Skull of a new born Child with Acrania.

a, a, frontals; *b,* nasals; *c, c,* very convex zygomatic bones; *d,* small ensiform processes; *e,* sella turcica; *f, f,* alæ majores ossis sphenoidei; *g, g,* petrous bones; *h,* basal part of the sphenoid bone; *i, i,* condyloid parts of the occipital bone; *l, l,* depressed squamous parts of the occipital bone; *m,* small osseous laminæ, representing the parietal bones.

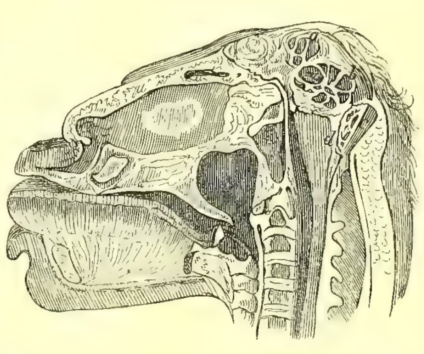
Second Type. — *The denuded surface of the basis cranii occupied by a spongy substance, instead of brain.* — In most cases vesicles, filled with a serous liquor, were observed to occur in this spongy substance, and with these occasionally also medullary corpuscles, which may be considered as rudiments of brain. There is sometimes a rudiment of the cerebellum, together with a rudiment which is continued into the spinal medulla, as though it were a medulla oblongata. The cerebral nerves are sometimes quite separated from, sometimes united with, the spongy substance. Sometimes they have the form of complete or lacerated bags, which extend along the superior surface of the skull and the posterior surface of the spinal column. The spinal column is either perfect, or partially, and sometimes entirely, cleft. The last of these conditions is represented in *fig.* 608.

Fig. 608.

To this form of monstrosity Geoffroy St. Hilaire gives the name of *anencephalus*. Specimens of it were found amongst the Egyptian mummies in the sacred sepulchres of the *Cynocephali* and *Ibis*, which is a very interesting fact as regards monstrous births in those times.

Third Type. — *The surface of the basis cranii only partially denuded, — a spongy tumour occupying the place of the brain.* The skull may be closed at its posterior part, and remain open at its summit. A more or less malformed cerebral substance appears on the summit of the skull, just as if it were

Fig. 609.



Section of the Head of a Child with Acrania, to show the union of the malformed brain with the spinal cord.

a, b, cellular sacs, taking the place of the brain; *c,* occipital bone; *d,* spinal cord.

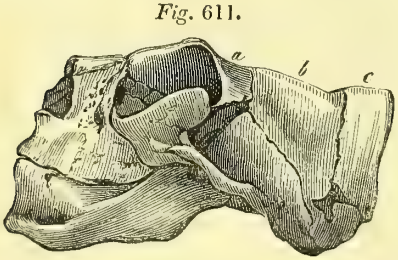
a hernia. The parietal bones are sometimes present, together with flat frontal bones, and a perpendicular occipital bone, so that the summit of the skull is quite closed, with the exception of a small opening. *Fig.* 609. shows how the malformed cerebral substance is applied to the medulla spinalis. All the cerebral nerves are present.

This form of monstrosity has in general a less brute-like aspect; the trunk is more evolved, and the whole body in general very heavy.

Fourth Type.—*The skull flat, more evolved, but having an opening, through which the brain protrudes as a hernia.*—This is what we call a cerebral hernia (*hernia cerebri, encephalocele*), viz. a tumour covered with the external integuments arising from some part of the surface of the skull, and containing a part of the brain. It has commonly the form of a bag, appended to the posterior part of the skull, and resting on the neck. The head is never turned with the face upwards; the ears do not rest on the shoulders; the neck is not wanting. The summit of the skull is flat and closed, and its cavity is too small to include the brain, which for this reason is placed on its outside, and backwards. The occipital bone has the form of a vertebral arc, which surrounds the brain, lying at the outside. *Fig.* 610. shows the external appearance of this monstrosity, *fig.* 611. the structure of the skull.

Fig. 610.

Fig. 611.



a, frontal; *b*, parietal; *c*, occipital, bones.

In many of the published observations, a collection of serous fluid accompanied the *hernia cerebri*, by which a *hydro-encephalocele* was formed.

The situation of the cerebral hernia is in general on the occiput, but sometimes on both sides of the root of the nose (W. Lyon, Kelch); above the eye (Adams); on the forehead (Beclard, Saxtorph, Niemeyen, Bredon, Guyenot); on the fontanella magna (Held); in the parietal bone (Le Dran, Stein, Tren); on the glabella, between the orbits (Otto).

On a survey of these various types, it appears that they all belong to the same class of monstrosities. The nature of the malformation is in all the same, namely a defective developement of the skull and of the brain. This takes place in different degrees, so as to convey us gradually from the complete want of brain to those cases in which it is nearly perfect, and differing from the natural condition only in situation. The constancy of form is very interesting in this monstrosity, so that the malformed children resemble each other nearly in every museum, and the published observations are quite accordant with the cases now occasionally occurring. This proves that the origin of the malformation cannot be accidental. The want of the neck, which is the reason why the ears rest on the shoulders and the chin on the breast, and which gives to this form of monstrosity such a peculiar character, is often the consequence of the want of some of the cervical vertebræ (Rathke, Haller, Otto), or of their mutual coalition (Rathke, W. Vrolik), or of their shortness (Sandifort.) As a transition to the brute form, this shortness of the neck is interesting, reminding us of the condition of the Cetacea. The prominence of the eyes is occasioned by the flatness of the orbits, and by the backward direction of their superior margin. It differs from the manner in which the eyes are prominent in children with internal hydrocephalus. A rich growth of hair is common to all the forms of *acrania*. Is not this, and likewise the abundance of areolar tissue, to be attributed to a vicarious nutritive function? The frequent absence of the suprarenal glands (Otto), or at least their imperfection and smallness (Morgagni, Hewson, F. Meckel, Soemmering, W. Vrolik) in all acranial fœtuses is remarkable. The capacity for persistent life after birth differs according to the different forms of this monstrosity. Acrania does not seem to interfere with uterine life. The children who are affected with it are all well nourished, and some of them even very large, at the moment of their birth. Nevertheless, they rarely live longer than a few hours. During this short life they offer some symptoms which are attributable to the reflex action of the nervous system; such as, for instance, muscular contractions when the skin is touched, rejection by the mouth of the recently expressed juice of *Pelargonium tomentosum*, and the attempt to suck a finger introduced into the mouth. In cerebral hernia the chance for the prolongation of life is greater. Some cases are known in which life lasted 20, 30, and even 60 years. When complicated with hydrocephalus, puncture has sometimes been instituted, but without success (Earle). Extirpation produced, in another case, instantaneous death.

What are the causes of *acrania?* From some of its forms, it is clear that there has been hydrocephalus followed by disruption (Morgagni, Penada, Sandifort, Klein, Otto). In an embryo figured by M. Schroeder Van der Kolk, the summit of the head is extended by hydrocephalus, and has on its superior surface a black gangrenous spot which seems to prognosticate a rupture.

In another fœtus I observed a fissure in the midst of an analogous spot. According to my opinion, the lacerated bags, which are sometimes found on or in the summit of the naked internal surface of the basis cranii, or at the back part of the more developed skull, are caused by such ruptures. Tiedemann gives a description of such a bag, filled with serous fluid, but not yet burst, and situated upon the head of a fœtus, which has the external appearance of *acrania.* (*Fig.* 612.)

Fig. 612.

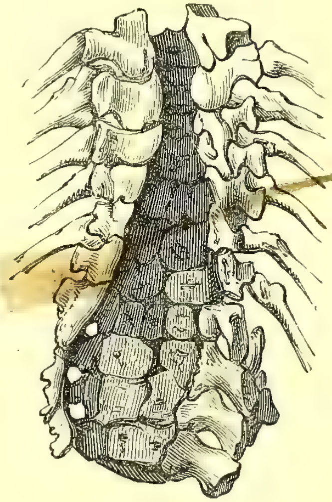
But in those cases in which the flat basis of the skull is only covered with a membrane and with cerebral nerves, in those in which there is a spongy substance upon it, and in those in which the skull, although flat, is otherwise complete, not the least probability exists of the rupture of a cerebral vesicle at an early period of formation. I am able to prove this, I think, by a small fœtus of two months, in which the superior part of the skull is wanting, and in which a spongy mass occupies the place of the brain.

It shows that *acrania* may also be a primitive malformation, occasioned by the simultaneous malformation of the brain and of the skull. Why I do not impute these malformations to external injury, such as the leaping of a monkey on the belly of a pregnant woman (Sandifort), to a fall down stairs (Pauli), or to the influence of imagination, needs not be demonstrated.

III. *Fissure of the Back Part of the Body.*

Hydrorachis and *Spina bifida.* — Fissure of the spinal column (*spina bifida*), and dropsy of the spinal medulla, occur each separately, or connected together. In the highest degree of fissure, the vertebral bodies even are cleft (J. T. Meckel, Tulp, Fleischmann). *Fig.* 613. represents such a case, after Cruveilhier.

Fig. 613.



In a less degree, the vertebral bodies are complete, but their arcs very defective, being completely wanting, or laterally incurved and fused together. In the lowest degree, the two halves of the vertebral arcs are completed, but not united together, so that posteriorly an open space remains between them, and a fissure occupies the place of the *processus spinosi,* which are separated into two lateral and equally incurved parts.

When this form of fissure of the spinal column is not accompanied by *hydrorachis,* both parts of the vertebral arcs are not bent laterally, but meet each other so exactly, that no open space remains between them. Sometimes the fissure is extended over the whole vertebral column (*spina bifida totalis*), sometimes it is but partially cleft (*spina bifida partialis*). The partial fissure occurs more frequently in the lumbar than in the cervical region of the column. The cause of the greater frequency of the partial fissure in the lumbar region is to be imputed to the termination of the spinal medulla in this region; to its expansion there under the form of cauda equina; to the larger sheath formed there by the dura mater; and to the very limited tendency which the osseous nuclei of the lumbar and sacral vertebræ show to unite themselves into an arc, which therefore remains always open at the inferior part of the sacrum. Although it occurs sometimes alone, this sort of fissure is generally accompanied with dropsy of the spinal medulla (*hydrorachis*), that is to say, with a sac of a reddish-violet colour, in which fluctuation is easily discerned. Its external covering is sometimes formed by the skin, and then it has the usual colour of the body; the skin, however, does not in most cases cover the whole surface of the tumour, but ceases at its circumference, and the rest of its surface is only covered with the dura mater. When the child lives, the dura mater becomes, after some time, thicker, harder, and more solid. When the tumour is covered with the skin, the dura mater is to be found under it. These membranes become often so thick, and so intimately united together, that it is nearly impossible to separate them from each other. The serum contained in the tumour is of a very variable quality, principally composed of albumen, mucus, gelatin, and muriate of soda (Bostock). It is effused between the pia mater and the arachnoidea, or between this and the dura mater, or in the primitive canal of the spinal medulla. If this canal remains open, the *hydrorachis* is in general accompanied with *hydrocephalus internus*. Sometimes these sacs are found on more than one spot of the spinal medulla, or divided into two by a septum. The size of the sac varies, and the complication with hydrocephalus is very dangerous. If this is the case, the artificial opening of the sac has a very injurious effect. Convulsions and exudative inflammation are in most of the cases excited by it. In some very rare cases the operation was attended with success. Sir Astley Cooper healed *hydrorachis* by reiterated puncturing with a thin needle and by compression of the tumour. Dubourg is said to have treated it with success by means of excision of the tumour and bringing together the lips of the wound with needles, in the same manner as in the operation for hare-lip. Beynard tied a ligature round the sac. E. de Thinecourt compressed the tumour, after having opened it, with two small rods, which he connected and pulled together by means of ribbons. The noxious effects of *hydrorachis* after the child's birth make it necessary to try an operation. Before birth this malformation seems not to have the least influence upon the health of the child: it is well nourished and duly constituted. After birth the noxious effect is modified by the different seat of the tumour. When seated in the lumbar and sacral region, it is the least dangerous. It is known that some individuals have lived with it twenty-eight years. In most cases, however, paralysis of the inferior part of the body is its consequence. *Hydrorachis* in the cervical region is much more dangerous. One case of this is mentioned in my "Tabulæ," in which death suddenly occurred on opening the tumour.

Besides *hydrorachis*, some other malformations of the spinal medulla are observed sometimes to accompany fissure of the spinal column: 1. Complete want of the spinal medulla, commonly connected with *acrania*; 2. Its appearance under a cylindrical form, with persistance of the primitive medullary canal (Morgagni, Santorini), which is sometimes double (Gall, Von Ammon); 3. Fissure of the spinal medulla into two juxtaposed cords; so that it seems to be double, which is occasioned by an arrest of developement at that period of its evolution in which the two halves, of which it is formed, are as yet separate; 4. The presence of a simple nervous expansion instead of spinal medulla; 5. The lamellar form of the medulla; 6. A too great length.

By all this it is proved, that fissure of the spinal column may be accompanied with *hydrorachis*, and with an imperfect developement of the medulla. They are totally independent of each other, and each is produced by its own cause. It is, however, not very improbable that a voluminous sac on the medulla may prevent the union of the points of ossification, by which the vertebral arcs are to be formed; but we are not, I think, justified in concluding from this that *hydrorachis* is the cause of the fissure of the vertebral column. For it may exist without fissure of the spinal column, if it has not acquired the form of a bag; and the spinal column may be cleft although the spinal medulla is intact. This leads me to the conclusion, that malformation of the spinal medulla, *hydrorachis*, and fissured spinal column, do not essentially go together.

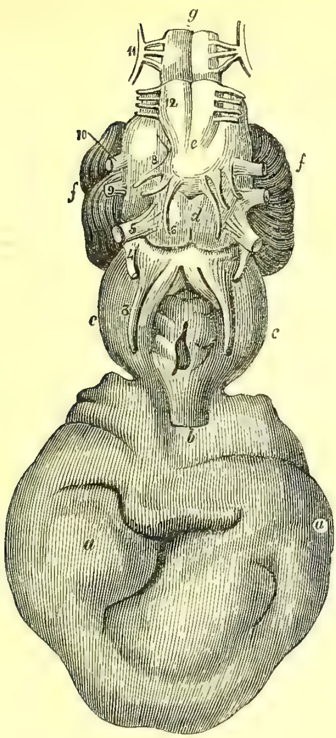
IV. *Hydrocephalus congenitus.*

Congenital dropsy of the brain.—Under this name we understand such a great volume of the head in a full-grown fœtus that it opposes in general a mechanical impediment to parturition, which can only be removed by an artificial diminution of the volume of the head. Its forms are — 1. *Hydrocephalus internus;* 2. *Hydrocephalus externus.*

1. *Hydrocephalus internus* is said to exist when the abnormal serous secretion occurs in the ventricles of the brain, wherefore it has also acquired the very rational name of *hydrops ventriculorum cerebri.* It may be an altogether primitive malformation, when the brain is arrested at that period of its developement in which it has the form of a very thin vesicle, filled with a serous fluid. I have observed this condition principally in Cyclopes, and give an example of it in *fig.* 614.

In such case there is no indication of the hemispheres, nor of the convolutions of the brain, and, in general, no difference to be seen between the white and the grey cerebral substance. In small fœtuses of two months, in which the bones of the skull could not yet be discerned, this form of hydrocephalus has

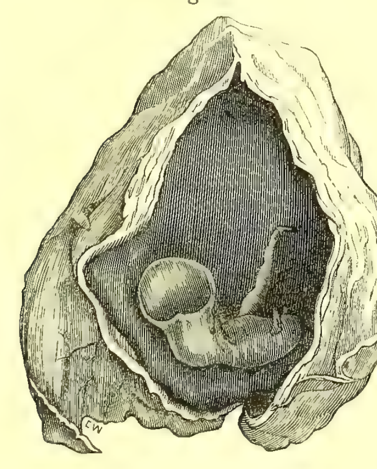
Fig. 614.



Brain of a new-born Lamb with Cyclopia.
a, a, medullary expansion filled with serous fluid; *b,* optic nerve; *c, c,* peduncles of the brain; *d,* pons varolii; *e,* medulla oblongata; *f, f,* cerebellum; *g,* spinal medulla; 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, the cerebral nerves, existing besides the optic nerve.

been observed (G. Vrolik, Rudolphi). See *fig.* 615.

Fig. 615.



(*Altered from Rudolphi by W. Vrolik.*)

Human Ovum, with an Embryo of two months, affected with hydrocephalus.

Internal hydrocephalus is, however, not always occasioned by arrest of developement in an early period of formation, but may be produced by chronic inflammation, (G. Vrolik), to which the child is, without doubt, as much subject during uterine life as after its birth. The principal causes of it seem to be external injuries suffered by the pregnant woman, and sometimes even reiterated contact by the act of copulation, if the pelvis is large, and the womb seated very low. Pseudo-membranes are on this account often found on the internal surface of the expanded ventricles (G. Vrolik), by which the deposition of the serous liquor may be limited to one or more of the cerebral ventricles, so as to produce an a-symmetrical expansion of the head; this is, on the contrary, symmetrical, if both the lateral with the third and fourth ventricle are equally and universally extended by the fluid. The head acquires, in such case, an enormous, but symmetrical, volume (E. Sandifort, W. Vrolik). The slower such a secretion of fluid takes place, the slower the head increases in volume, and the less it endangers life, and the less the free evolution of the mental faculties is interfered with. Some cases are mentioned, in which life lasted sixty years (G. Vrolik), thirty years (Michaelis), and fifty-four years (Gall). It is remarkable that in many of these cases, neither the senses nor the intellectual faculties were in the least impaired. This proves that the substance of the brain is not altered by it, and that the form only of the brain is changed by the unfolding of its convolutions. This unfolding is the consequence of the pressure which the fluid exercises from the inside towards the outside, and of the thereby augmented volume of the ventricles (Hunauld, Gall). Those who presume that through the influence of the serum exudated in the ventricles the dissolution and even the total destruction of the cerebral substance may be effected, go evidently too far (Cruveilhier). However large may be the surface into which the hemispheres of the brain have been unfolded, the white medullary substance can always be distinguished from the grey (G. Vrolik). The parts contained in the ventricles are sometimes intact (G. Vrolik), but sometimes incompletely developed, and what we should call depressed (Aurivillius, Büttner, Malacarne, Klein). The corpus callosum assumes a thin lamellar form; the septum pellucidum and the fornix become thinner; the glandula pituitaria and pinealis deviate in general from their natural condition (Friend, Malacarne, Wrisberg). The cerebral nerves are in general not changed, and the cerebellum is in most cases natural. The lumen of the cerebral arteries is commonly very large (Büttner), and Friend saw two internal carotids passing through the carotid canal of the right side. In a few cases there was observed a degeneration of the cerebral substance, which resulted in a deranged and feeble state of the mental faculties (Büttner).

Internal hydrocephalus has always a prejudicial influence upon the condition of the rest of the body, principally upon its nutrition and upon the osseous system, which it predisposes to emollition. It has a very great influence on the bones of the skull. Its effects are: —

a. A large expansion of the skull, whilst the face preserves its common shape, and is in great disproportion to the enormous circumference of the skull. This disproportion is the most significant symptom of hydrocephalus, and distinguishes it from simple amplification of the head.

b. A protuberance of the frontal tuberosities, which is to be considered as an arrest at an early period of developement, occasioning an enormous augmentation of the facial angle, which greatly exceeds a right angle.

c. A pushing downwards of the orbital parts of the frontal bone, which makes the superior orbital margins to disappear totally, and to form a protuberance with the frontal part of the frontal bone. The eyes thence acquire a strange direction, their axes being turned upwards.

d. A-symmetry of the hydrocephalous head, which is always more or less oblique. This is the effect of the unequal expansion of the brain. To this may also be ascribed the strange form which the skull acquires when it is regularly extended and developed on its fore and lateral parts, whilst the occiput has a very singular prominence. Such a form is, without doubt, occasioned by a regular expansion of both the hemispheres of the brain up- and sidewards, whilst their posterior lobes and the cerebellum have preserved their regular form. The parietal bones are thereby expanded and augmented in circumference, whilst the occipital bone, not participating in the expansion, is disproportioned to the rest of the skull. The parietal bones are removed from it, so that, during the primitive ossification, an interval is formed, which is afterwards filled up with Wormian ossicles.

Not less singular is the form of the head and skull, when, probably on account of the position of the head in the womb (as is the case in a *partus pedibus prævüs*), the pressure of the fluid has been exercised principally downwards, so as to extend chiefly the lateral parts of the head.

e. An abnormal disposition of the cranial bones. The fontanellæ acquire, in the first instance, a very large dimension, and some parts of the cranial bones remain cartilaginous, which parts are, in a more advanced period, filled up with Wormian ossicles. Baillie asserts, that sometimes the already formed sutures are opened by the serum exuded in hydrocephalus internus. In other cases, the want of closure of the sutures is to be imputed to a too great thinness of the bones.

2. *Hydrocephalus externus* is by some (Monro, Wrisberg, Hartell) erroneously considered as the result of *hydrocephalus internus*, followed by laceration of the cerebral hemispheres. It is proved, by a great many observations, that such a laceration occurs very seldom. The fluid is, in most cases of hydrocephalus externus, exuded on the surface of the brain. This may be the consequence of an arrest of developement, as I observed in a cyclopic lamb, but it may also be produced by inflammation. The serum is accumulated between the dura mater and the skull, or between the two layers of the arachnoid membrane, but in most cases its situation is between the dura mater and the arachnoid membrane. In all these cases the brain is strongly compressed, shrunken, and hard (Kaltschmidt). Dullness and somnolence are, according to Frank, the consequences of hydrocephalus externus, and convulsive affections those of hydrocephalus internus.

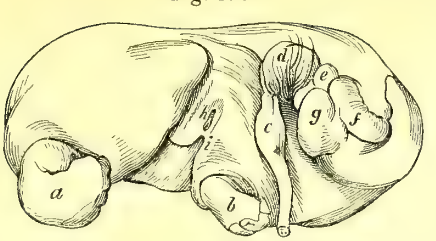
V. *Acephali, or Fœtus without a Head.*

When we observe the fœtus in its first periods of developement, the head is not yet clearly distinct from the trunk. From the third to the fifth week of gestation, the head, not previously discernible, grows so rapidly, that it has in the fourth week acquired the same volume as the trunk. Now the developement of the fœtus is sometimes arrested at that early stage when the head is not yet distinguishable; the result of such an arrest must manifestly be an *acephalus.* This denomination is, again, as erroneous as many others; for not only the head, but many other parts, are wanting. The question remains whether a more appropriate name could be given. Gurlt tried to do so, but, I fear, not with good success. He calls the lowest form of acephali *amorphus globosus,* which is a true *contradictio in adjecto.* I think it therefore proper to preserve the old name of *acephali,* to which I refer, as has been done by Tiedemann and G. Vrolik, nine types, for which I think it not necessary to give special names.

First Type. — *Acephali in the form of a rounded mass, without any indication of extremities.* — Examples have been given by G. Vrolik, Bland, and W. Vrolik, all of twins. The rounded mass is covered with the skin; it contains an intestinal fold, and receives the insertion of the umbilical cord. In general there is found in it the rudimental indication of vertebræ and of spinal medulla.

Second Type. — *Acephali in the form of a rounded mass, with indication of feet.* — The chief observations of this form have been given by G. Vrolik and Clarke, in cases of twins. They have an umbilical cord, rudimental external genital parts, and an anal orifice, with an imperfect abdominal cavity, in which are contained an intestinal loop formed by a colon and cæcum, and kidneys. Consequently all the thoracic viscera, the liver, the spleen, pancreas, stomach, and the small intestines, are wanting; but there is a rudiment of a nervous system, a tolerably complete right inferior extremity, a pelvis, and a left separate foot, without femur and crus. (*Figs.* 616, 617.)

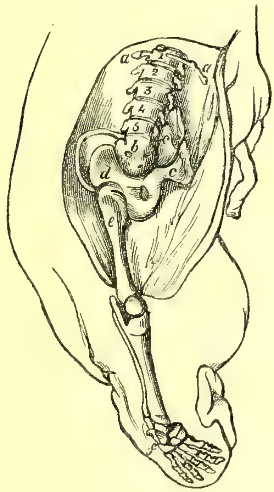
Fig. 616.



Human Acephalus, born along with a well-formed child.

a, the right foot with five; *b*, the left, with three toes; *h*, the female genitals; *i*, the anus; *c*, tumor formed by the umbilical cord; *d, e, f, g*, eminences covered by the skin.

Fig. 617.



The same Acephalus with dissection of the skeleton.

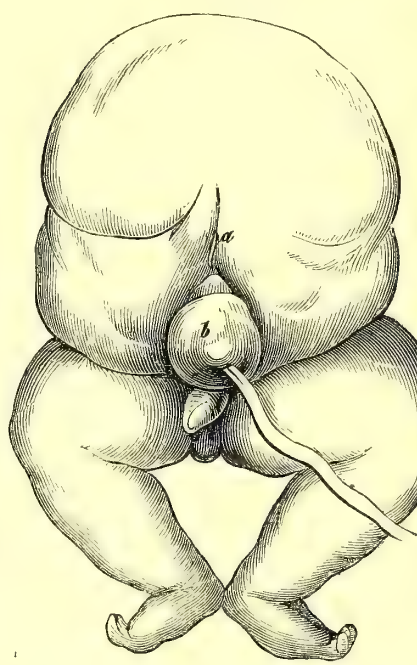
a, a, the only obvious inferior dorsal vertebra, with a pair of ribs; 1, 2, 3, 4, 5, lumbar vertebræ; b, sacrum; *c, c, d*, iliac bones; *e*, femur; *f*, bones of the foot.

Third Type.—*Acephali in which the trunk is more developed, without a head and thoracic or superior extremities, but composed of an incomplete trunk, with an imperfect inferior extremity.* — In the lowest grade of this monstrosity may be ranked an acephalus observed by Ruysch, consisting only of a leg. Somewhat more perfect is the acephalous inferior extremity of a goat, mentioned by Hayn. It consisted of a pelvic bone, with the other bones of the inferior extremity, some muscles, the vessels and nerves of the femur, which were probably connected with the umbilical cord of the perfect goat born at the same time as the acephalus.

Fourth Type. — *Acephali in which the trunk is more developed, without a thorax and without superior limbs, and composed of an abdomen, genital organs, and two inferior limbs.* — The hypogastrium and the two inferior limbs are, then, more or less completely formed parts. With exception of one, all the observations which we know of it are of twins, and in one case of three children born at one birth. In many it is proved that the mother of the acephalus has been often fecundated. They are rarely full-grown at birth, and they have in most instances a placenta common to them and the well-formed child, but with a separate cord; the fœtal membranes also appear to be common to both. The cord of the acephalus contains sometimes two, sometimes three or four vessels (T. H. Kalck). The integuments of the monster, truncated at its upper part, are irregularly tumified, by a large quantity of thick, pale, or yellowish subcutaneous cellular tissue. Interiorly there are lumbar vertebræ, with a pelvis, and the bones and muscles of inferior limbs, besides the spinal marrow and its nerves; the lumbar and sacral parts of the sympathetic nerve; blood-vessels without a heart, of which the arteries are connected with the umbilical arteries, and the veins with the umbilical vein; a loop of intestines; uropoietic, and genital parts. All the other parts are wanting.

Fifth Type. —*Acephali in which the trunk is much more developed, with an imperfect thorax, composed of some dorsal vertebræ and ribs. The superior limbs are wanting.* — The only difference between this and the preceding type is in the more complete trunk, there being a thorax superadded to the abdomen. In all the other points the structure resembles that of the fourth type; they are

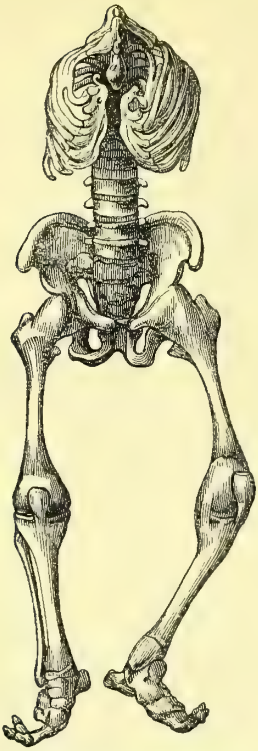
Fig. 618.



Human Acephalus born along with a well-formed child.

a, cutaneous fissure in the lower part of the thorax; *b*, umbilical hernia, under which are the male external genital parts.

Fig. 619.



The skeleton of the foregoing Acephalus.
a, mobile bone connected with the single cervical vertebra.

always twins, and not full grown. As far as it has been mentioned by different observers, there is either a common placenta, with two cords (Ponjol), or with one cord split into two (Mery); or there are two placentæ connected together (Herholdt); or there are two totally separate ova, with a double placenta (Monro). The external appearance differs from that of the fourth type, by greater length, and less truncated upper part of the body, in which a feeble indication of head may sometimes be visible (Ponjol, Prochaska). The integuments are as in the fourth type; the toes are generally malformed; the arms and the external genital organs are often abnormal. To the lumbar part of the spinal column is joined an imperfect osseous thorax, sometimes with cervical vertebræ (Hevermann), but without thoracic viscera. The diaphragm exists in most cases. There are vessels without a heart, which cohere with the umbilical vessels. The viscera of the epigastric region are commonly wanting; Atkinson mentions only a liver. In some intestines can be recognised either as *intestina tenuia* or *crassa*. The uropoietic organs, and the internal parts of generation are commonly present. There is in all a spinal marrow. The observations as to the nervous system are very incomplete. (See *figs*. 618, 619.)

Sixth Type. — *Acephali with a trunk composed of a thorax and an abdomen, and with two superior and two inferior limbs.* — When the trunk is more developed, the thorax becomes more convex, is more distinct from the abdomen, and supports two superior limbs. These acephali, too, are twins, at least in the greater number of the cases. They are often not full-grown, and borne by women who have frequently been pregnant. The placenta is in general common to the two fœtuses, but with two cords. The thorax is more perfect than in the fifth type; the upper part of the body terminates not in an obtuse end, but in a broad and flat surface, having a fissure in the midst, with an indication of a head. The sternum is often rudimentary, and the osseous frame of the superior limbs is very incomplete. To the spinal column are added cervical vertebræ, and sometimes a confused indication of cranial bones. There is usually a diaphragm, but neither heart nor lungs. There are commonly two vascular trunks, an arterial and a venous. With the venous is connected the umbilical vein; and from the internal iliac arteries arise the umbilical arteries. There are uropoietic organs, and an intestinal canal, with a cæcal termination; and sometimes a liver. This latter is, however, sometimes wanting, together with the spleen and the pancreas. In the intestinal tube there is no meconium, but only a mucous substance. The nervous system is very incomplete; but there is constantly a spinal marrow with the abdominal part of the sympathetic. I have observed distinct muscles, of which the presence has been denied by others.

Seventh Type. —*Acephali in which some cranial bones are found.* — This has been observed by Herholdt, in a monster, born twin with a well-formed child, of a mother who had five other children. There was an amorphous head, with an indication of eyes and nose, but without ears and mouth: the rest of the body was much deformed. Of the cranial bones, the condyloid and vertical portions of the occipital only could be distinguished. There was no trace of facial bones. Analogous observations have been made by Curtius and Otto.

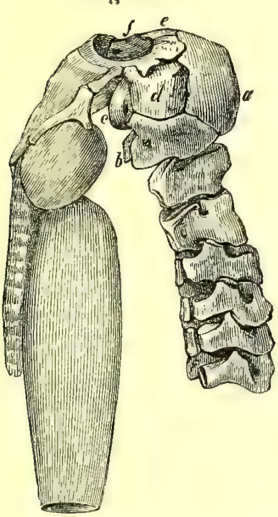
Eighth Type. — *Body and extremities perfectly well developed, and having a neck, which is wanting in the other types. The neck is surmounted and terminated by the ears.* — This is the form to which Gurlt gives the name of *perocephalus aprosopus.* I have met with it in the lower animals only. The body and the limbs are perfectly well developed; on the perfect neck are placed two coalesced ears, behind which there is an imperfect cranium, composed principally of the cranial, *minus* the facial, bones. In all this the deformity makes a transition towards an imperfect formation of the face. (*Figs*. 620, 621.)

Ninth Type. — *Acephali which are composed of the trunk only, without the least indication of superior or inferior limbs.* — Only one case of this monstrosity is known, observed by Vallisneri. In a fœtus of a very mature period of

Fig. 620.

The superior cervical part of a perocephalous lamb, terminated by the ears which are coalesced with each other.

Fig. 621.



The skeleton of the parts represented in fig. 620., *with the trachea and the œsophagus.*

a, squamous part, and *b,* condyloid part of the occipital bone; *c,* petrous; *d,* squamous, part of the temporal bone; *e,* parietal bone; *f,* auditory bones.

evolution, the head, the superior and the inferior limbs, were wanting. There existed only a trunk, which contained a tolerably large heart, imperfect lungs, a malformed liver, a stomach, and an intestinal canal.

From this survey of the characteristics which distinguish the acephali, we learn that they are born with two, three, or four other fœtuses at one birth. Can this quantitative multiplication of the children be the cause of the qualitative malformation of one of them? This is probable by the great fertility of the mothers of acephali, which also indicates that these monsters are produced by an arrest of developement. It is very easy to reduce their external appearance to the early periods of developement, in which the head is not yet distinct from the trunk, and in which the limbs are not yet protruded. It is worth mentioning that the abdominal cavity, with the kidneys and a part of the intestinal canal, are the most constant organs, which is very interesting with reference to the genesis of the intestinal tract. In the monstrous births of the second, third, and fourth type, there is only a colon, while in those in which a thorax is superadded (as in the fifth and sixth types), there is also an *intestinum tenue* with the cæcum. I regard this as a confirmation of the statement, that the formation of the intestinal canal commences at the two extremes, and proceeds from these to the middle part.

In the same manner the uniformity of circumference of the whole intestinal tube is an arrest of developement at an early period of embryogenesis, to which may also be referred the cæcal beginning, and in many cases even the cæcal termination of the intestine. The frequent deficiency of the liver is the consequence of the absence of the stomach and duodenum, and therefore a sign that the liver is a protrusion of the mucous membrane of the intestinal tube. The connexion between the containing and the contained parts is also very distinctly proved by the acephali. The very general presence of the lumbar part of the spine determines the existence of kidneys; that of the pelvis, the existence of the urinary-bladder and of the genital organs. The very imperfect condition of the thorax is in relation with the absence of the heart. The presence of vessels without a heart demonstrates that the circulation of the blood can be carried on by these alone, and that the formation of vessels is quite independent of that of the heart. The profusion of cellular tissue, by which the swollen appearance of the acephali is produced, may be formative substance, which has not been employed in the production of the other parts of the body, and which has therefore grown rather abundant. In this manner many of the peculiarities of the acephali can be reduced to fixed principles.

VI. *Want and defective Formation of the Trunk** (*Acormia*†).

The highest degree of this kind of monstrosity is where neither trunk nor limbs are formed. Lycosthenes, Rudolphi, and Nicholson describe monstrous births, in which the head is the only part formed.

a. Sometimes only a part of the head is ormed, of which I saw an example in a monstrous fœtus born with a well-formed calf. The tongue was the only well-developed part in it. This shows that in the absence of all the central organs, heart, lungs, skeleton, and brain, there may be a well-constituted skin

* The word *trunk* is here used to include the extremities.

† From ἀ, privativum, and κορμὸς truncus.

surrounding an amorphous mass of cellular tissue, and only a single well-formed organ. I have given a fuller account of this case in my Tab. lxii. *figs.* 4, 5, 6. Therefore we may conclude that each part is formed *sponte suâ*, and that it is in its evolution quite independent of the rest of the body.

b. A less degree of malformation is when the superior part of the body is formed without the inferior limbs. *Fig.* 597. gives a representation of this monstrosity, of which a succinct account is to be found in my Handbook, D. ii. Bl. 100, and Tab. lxiii.

c. In a more perfect developement of the trunk one of the extremities may be wanting.

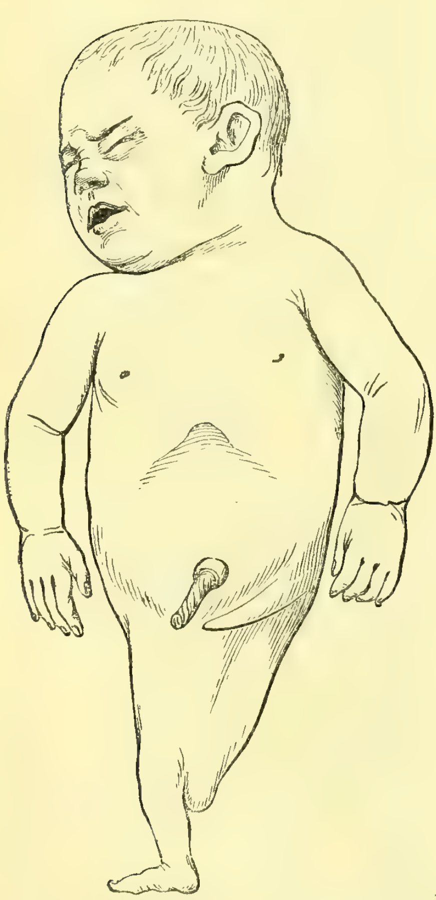
We call this malformation *monopodia;* in it one of the inferior half-parts of the body has not been formed. It makes a transition to those monsters, in which the inferior extremity of the body tapers gradually into a tail-like form, which has given to them the name of *monstra Sireniformia.*

d. *Sympodia* or Siren-like form is the fourth species of defective formation of the trunk. The single inferior extremity is composed of the elements of two, and articulates with a pelvis, which is not formed, as in *monopodia*, by one bone, but by a coalescence of two. In most of them the partially double, partially single inferior extremity terminates in a caudal point; on account of which the name of *Sirenes* has been adopted. To this imperfection are added closed anus, defect of external genital parts, and the existence of but one artery in the umbilical cord. The malformed inferior extremity has not always the same form. Therefore we admit three varieties: — 1. Without a foot, *Sirenomelia* of J. G. St. Hilaire; 2. With a single foot, more or less complete, *Uromelia* of J. G. St. Hilaire; 3. With a double foot. *Fig.* 622. represents the second, and *fig.* 623. the third variety.

Fig. 623.

Sympodia.

Fig. 622.



Uromelia.

By this survey of the four types of defective formation of the trunk is proved that they form a very natural series, in which we are gradually inducted, from the total want of a trunk to monsters in which inversion of the inferior extremities is the only deviation from the natural form. The same regularity is here to be observed as in every other class of monstrosities. It is therefore impossible to ascribe their origin to accidental external causes. Meckel has opposed his own peculiar and sarcastic wit to this absurd ætiology, and gives the very ludicrous account of a surgeon who supposed that the Sireniform monster had been formed during a very difficult delivery. If it is, on the contrary, an original malformation, it may be asked, what can be its remote cause? Is it the original want of one of the umbilical arteries? I should not think so; for one of these arteries is also wanting in the variety in which all the parts of the two extremities are present, and we know that one of them may be wanting in a completely well-formed child. (See p. 948.) Another question is, whether *sympodia* can be attributed to the coalescence of the inferior extremities (Meckel, Kamm, Boerhave, and Cruveilhier). Neither am I inclined to adopt this cause.

1. I cannot imagine a coalesence of bones so complete, that through these could be formed one single extremity.

2. It is impossible to explain by it the imperfect condition of the leg and of the foot in the majority of cases.

3. From such a fusion or coalescence cannot be derived the imperfect state of the rectum, and of the sexual and uropoietic organs.

It seems to me more probable that *sympodia* is due to some original malformation of the pelvis and its viscera, of which the cause remains unknown. The formation of a head solely, of an incomplete trunk without the lower limbs, or of a single inferior extremity, is certainly to be attributed to nothing else but impeded developement. It shows, moreover, that the different parts of the body are quite independent of each other in their original formation.

e. *Original defective formation of the pelvis.* In a well constituted body the pelvis may be originally malformed, as is proved by the *obliquely narrow pelvis* of Nazele, and by the *transversely narrow pelvis* of Robert; of which malformation the cause is to be found in the imperfect formation of the sacrum.

f. *Defective developement of the spinal column.* This has been principally observed in calves. It is too short, defective, more or less incurvated, and some of the vertebræ fused together. The head is situated at a short distance from the thorax; the tail and the anus are reflected to the dorsal surface; the pelvis is too narrow, and turned upwards at its posterior part.

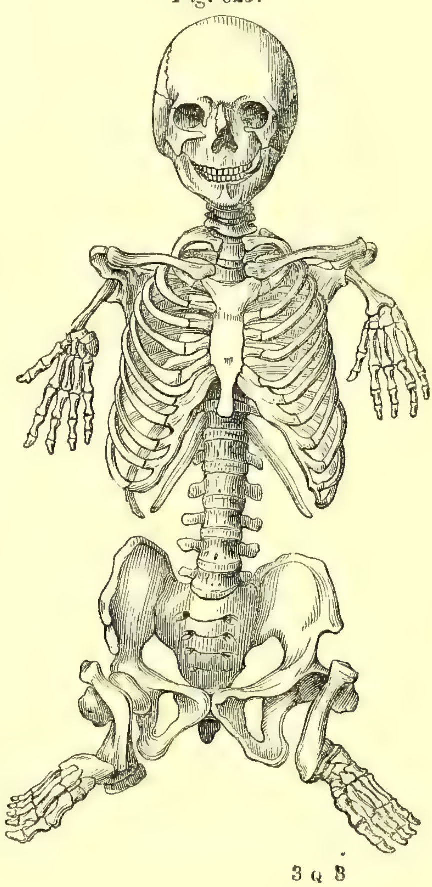
VII. *Defective Formation of the Extremities.*

The origin of many malformations of the limbs may be referred to the early periods of embryogenesis. But for some of them this is impossible.

1. *Want of all the extremities* is an arrest of developement at that period, in which the limbs are not yet formed, and in which small tubercles occupy their places. Sometimes the superior extremities only are wanting, which urges the inferior extremities to acquire a sort of dexterity by which they may in some measure supply the place of the superior limbs. Of all the examples which are known of it, that of Thomas Schweicker is the most memorable. The inferior limbs only are rarely

Fig. 624.

Fig. 625.



wanting, and the cases few in which there is but one superior or inferior extremity.

2. *Want of the intermediate parts in the extremities, so that the hand is attached immediately to the shoulder, and the foot to the hip.* — This may happen in one or in more extremities. Of the last, a very interesting example occurred in the person of a certain Marco Catonze, of whom I represent the external appearance and the skeleton in *figs.* 624, 625., referring for more details to my Tab. lxxvii.

3. *Limbs too short.* — All their parts exist in such case, but are too short, as if they were not full-grown. The malformation is however not limited to the extremities, but extends over the trunk and the head. The head has in all the known cases the aspect of hydrocephalus. The neck is short and broad, the trunk short and swollen, and the limbs short, broad, and thick. Sœmmering and Otto ascribe this to congenital rachitis. But according to my opinion it ought to be attributed to defective developement, which is confirmed by the dissection, performed by C. Mayer, of such a monstrosity.

4. *Limbs which seem to be truncated.*— Sometimes the fore-arm and the leg terminate abruptly like stumps, and present the appearance of cicatrices. I saw this on the four extremities of a calf, of which I have represented the external form and the dissection in my Tabulæ lxxviii. and lxxix. In many of the known cases this defective condition of the limbs seems to be the result of arrested developement. In some others, however, it is the effect of mutilation produced by the constriction of the umbilical cord, or by pseudomembranes. Montgomery has given many examples of it in his article Fœtus in this Cyclopædia. It is an interesting fact that from these stumps may grow rudiments of fingers, as Dr. Simpson showed me during the visit which I paid him at Edinburgh.

5. *Diminished number of fingers and toes.*— The highest degree of this malformation is the existence of but one finger or toe. Sometimes there are only the thumb and the little finger, as may be seen in a preparation in the museum of Ilovius at Amsterdam. The greatest transition towards the natural condition is the presence of four fingers or four toes.

6. *Coalesced fingers and toes.* — In otherwise perfect limbs it is possible that hands and feet may be arrested at that inferior degree of developement, in which they are not yet separated into fingers and toes. The child is then born with fingers or toes, which seem to be coalesced; but that is nothing more than a fallacious appearance. The malformation consists really in absence of fission. Of this there are different degrees: *a*, complete absence of fingers and toes, instead of which there is a common mass; *b*, connection of the fingers and toes by means of a membrane; *c*, the adhesion limited to the posterior parts of the fingers and the toes, while their anterior parts are completely free. All this may be seen in *figs.* 626, 627, 628

Fig. 626.

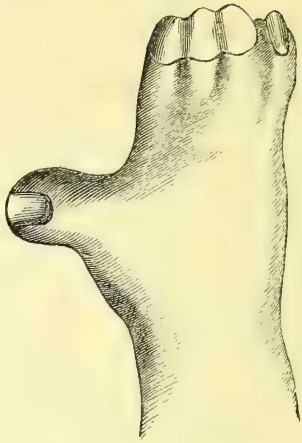


Fig. 627.

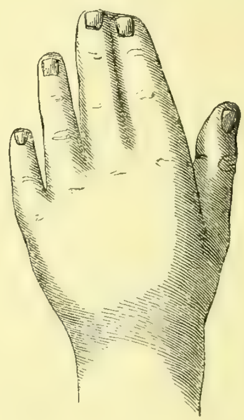
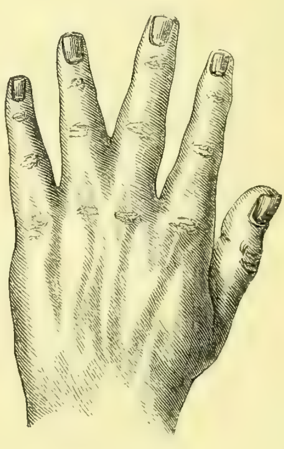


Fig. 628.



(*After Otto.*)

7. To all these malformations of the limbs ought to be added the abnormal direction of the foot; but this is fully considered in the

article Abnormal Conditions of the Foot in this Cyclopædia.

VIII. *Cyclopia.*

Upon this interesting malformation, which for many years was the object of my own investigations, I should have much to say; but my friend Paget has already given a succinct survey of its different forms in his learned Article Nose, to which, therefore, I refer. I beg leave here to add to the observations which I have published in my former works upon the origin of *Cyclopia*, a few additional remarks on the subject. Is it an arrest of developement? It cannot be denied that many deviations of the parts in Cyclopes may be referred to a previous natural form. For example, in one of my published cases the optic lobe and the brain formed one continuous part, which is certainly an early natural condition. It is also certain that the disposition of the hemispheres of the brain in Cyclopes, which appear to be a single vesicle, accords with the vesicular state of the brain in the first period of its developement, and that the unprotected situation of the ganglia of the brain, of the cerebellum, and of the medulla oblongata, may be considered as a fœtal condition. But, as to the eyes, it is not so certain that their singleness is the result of an arrest of developement. E. Huschke has, however, maintained the opinion, that the eyes are formed by a single vesicle, which becomes separated into two; but from the more recent and accurate investigations of Bischoff, we must conclude that the optic lobes are from the beginning separated and double, taking their origin from the anterior cerebral vesicle, and that from an abnormal condition of this last, by which the rudiments of the eyes approach each other and fuse together, may be derived the cause of *Cyclopia.* If this observation is true, of which it is difficult to retain the least doubt, *Cyclopia* really appertains to the *Verschmelzungs Bildungen* of Meckel in an early period of developement. Perhaps it may be compared with the metamorphosis of the eyes in *Daphnia*, *Cypris*, *Polyphemus*, and *Cyclops*, in which there are originally two vesicular bulbs, which subsequently coalesce into one. But however this may be, it remains certain that the malformation of the cranial and facial bones in Cyclopes is the consequence of the abnormal condition of the brain and of the visual and olfactive apparatus.

IX. *Deficiency of the Underjaw* (*Monotia*).

Want of the under jaw often coexists with *Cyclopia*. By this complication is formed a peculiar series of monsters, which make a gradual transition to those in which, notwithstanding the presence of two eyes, the under jaw is absent. I refer to this the following species.

1. *Total defect of the opening of the mouth,* — as observed by me in a lamb, in which also the ears were removed to the basis of the head and coalesced. The under jaw was totally absent; and behind the coalescent ears there was an osseous vesicular cavity, formed by the bulbous tympanic cavities, united together.

2. *The opening of the mouth represented by a fissure at the inferior surfaee of the face.* — The rest of the external appearance is similar to the first species. The under jaw is wanting, but there is a rudiment of a tongue.

3. *Too short an under jaw.* In man and the lower animals the under jaw is sometimes incompletely developed, and more depressed posteriorly than it ought to be. This original brevity of the under-jaw is the cause of a great many ulterior deformities.

Without doubt, these three forms of monstrosity make a continuous series. They consist, as Bischoff says, in an imperfect developement of the first visceral arc, by which the under jaw and the bones connected therewith are either wanting or defectively formed, the result of which is, that the ears are removed to the basis of the head, and there become fused together. The total defect of the opening of the mouth is the highest, the too short under jaw the least degree of malformation.

Herewith I conclude my brief account of the monstrosities resulting from arrest of developement. The description of the congenital abnormal condition of the different apparatus would oblige me to surpass the due limits of an Article for this Cyclopædia, which already, I fear, may be considered rather too long; and I think this the less necessary, because a great deal of information about them may be found in the Articles Anus, Diaphragm, Fœtus, Hermaphroditism. I therefore pass on to a succinct description of a second group of monstrosities.

B. Monstrosities produced by Excess of Developement.

I. *Fœtus in Fœtu.*

The human fœtus may be included in another fœtus, or adhere to its body. This may happen in two different manners: —

1. *A fœtus more or less perfect contained in the cavity of the body of its twin-brother or sister.*

a. *In the uterus.* — The fœtus would be pregnant in such a case at the moment of its birth. The observations given of it are, however, somewhat apocryphal.

b. *In the abdomen.* — In a case recorded by Fattow, there are, in a fœtus of seven months, two rudiments of fœtuses contained in its abdomen. Such observations are also given by Reiter, Heminger, Pacini, and E. Philips. In general, the rudiments of a second fœtus are very imperfect, and included in a sac. Sometimes, however, they are more complete, which was, for example, the case in an observation of Young, of which the preparation is preserved in the splendid Museum of the London College of Surgeons.

c. *In the anterior mediastinum.* — As in a case recorded by Gordon, in a female of twenty-one years.

d. *In the scrotum and the testes.* — Such cases have been noticed by Rosenberger, Hartmann, D. S. J. Wendt, Velpeau. Sometimes the rudiments of a second fœtus are found in the interior of the testis, sometimes at its exterior surface.

e. *In the stomach.*

f. *In the intestinal canal.* — Highmore has given such a case in a youth of fifteen or sixteen years, in the gut of whom an acephalus was found.

g. *In the orbit.* — According to Barnes.

h. *At the tentorium of the dura mater.*

i. *At the palate.* — It is then in the form of a fungous excrescence, consisting of the rudiments of a second fœtus (Otto, Sandifort, Ehrman, Stadenski).

2. *The more or less developed rudiments of a fœtus adhere, in the form of a tumour, to the external surface of a second body, and are covered by the external integuments.*

a. *To the cheek.* — G. Vrolik observed in a new-born male child, a sac of large circumference, covered by the external skin, and adhering to the region of the left cheek, but without communication with the mouth. In this sac there were tuberculous cartilages, osseous nuclei, and organised parts of indefinite form and composition.

b. *To the neck.* — According to Joube.

c. *To the epigastric and umbilical region.* — As recorded by E. B. Gaither.

d. *To the sacral and perineal region.* — This is the most frequent mode of adhesion, as is proved by a great many observations, among which those of Himly and of Fleischmann deserve special mention. This adhesion takes place in different manners: 1. by external cellular tissue; 2. by internal union with the abdominal and pelvic cavity (Himly, Schaumann, and Stanley); 3. by communication with the spinal canal. There is sometimes no vascular communication between the fœtus and its appendix (W. Vrolik); and in other cases there are large branches going from the *arteria sacra media* of the fœtus to the sac. In general, the sac has its own integuments, over which passes the skin of the fœtus. The genital parts and the anus are always quite separate from the sac, which merely lies in apposition with them. In the majority of the known cases, the rudiments of a fœtus contained in the sac are but confused and ill-determined organic substances, intermingled with a few osseous and cartilaginous nuclei. In one case it was possible to recognise the cranium with the face and the naked encephalous masses (Wedemeyer); Mayer and Blizard found an intestinal loop; Himly saw distinct super-maxillary bones, and rudiments of temporal, frontal, and sphenoid bones, &c.

If we take a survey of all the cases which are designated as *fœtus in fœtu*, it is clear that some may be compared with parasitical diseases formed in the interior of the body of the fœtus. I presume that this is the case, when the mass which is found consists only of hair, fat, teeth, and some osseous nuclei, contained in a cystic tumour. In other cases the rudiments of a fœtus are included with a more or less perfect indication of an ovum in the body of a second fœtus, or adhere externally to it. The large number of theories on the origin of this monstrosity have been criticised by Himly. It is certain that none of them can be maintained. It is most probable that the *fœtus in fœtu* is an incomplete effort to form a double monster. In this sense, some cases of *fœtus in fœtu* make a transition towards that form of double monsters which is named *heteradelph.*

II. *Double Monsters, in which one of the Fœtuses is more or less perfect and the other merely an Appendix to it* (*Heteradelphi*).

Under this name of heteradelphs, which we owe to Geoffroy St. Hilaire, we understand that species of double monsters of which one fœtus is large and perfect, and another, or part of another, adheres to it like a parasite. They should be considered as twins, of which one has been developed at the expense of the other, which other sometimes becomes partially included in its body. According to the more or less perfect state of the appendix, they are reduced to different species.

First Species. — *The appendix consisting of a head only.* — This may be connected: —

1. With the epigastric region (Winslow, Hesse),
2. With the cranium (E. Home),
3. With the back (Chabelard),
4. With the palate (Hofmann), or
5. With the under-jaw of the perfect fœtus (Geoffroy St. Hilaire, G. Sandifort).

Second Species. — *The appendix consists of more or less developed extremities only.* — Supernumerary extremities, more or less developed, are connected with some part of the body of a perfect fœtus, as:

1. Pelvis and two inferior extremities connected with the epigastric region of the perfect fœtus (Serres, E. Sandifort, Trombelli, Mayer, Winslow, Reschel, Buxtorff, Cantwell, Lycosthenes).

The appendix is sometimes more, sometimes less perfect; sometimes connected with the sternum, sometimes with the epigastric region or in communication with them by a cylindrical cutaneous prolongation. In the appendix are regularly formed organs of generation, kidneys, an intestinal loop in communication with the intestinal canal of the supporting fœtus, and vessels which anastomose with those of the latter. The adhering parasite is therefore one with its supporter.

2. Pelvis and the two inferior extremities connected with the lateral wall of the abdomen of the perfect fœtus (W. Vrolik).

3. Pelvis and two inferior extremities con-

nected with the pelvis of the perfect fœtus (Numan, Osiander, Haller).

4. Separate anterior or posterior extremities connected with some part of the perfect fœtus (W. Vrolik, Von Baer).

All these varieties are indicated under the names of *gastromele*, *pygomele*, and *melomele*.

Third Species. — *The appendix is an acephalus with four extremities.* — The union has as yet been observed only at the epigastric region of the supporting fœtus, through which the abdominal cavity was common to the two bodies. In the appendix the genital organs existed, but the anus was closed. In many cases, the evacuation of urine has been observed; the appendix showed circulation of blood; it had its own temperature, and was dependent for nutrition on the chief or perfect body. In the interior were found uropoietic organs, vessels connected with those of the chief body, and an imperfect intestinal canal (Otto, Serres). In the supporting fœtus are sometimes found traces of double organs (Otto, Serres, Rosenstiel).

Fourth Species. — *The appendix a complete body with a head and four extremities* (Bartholinus). — This form of heteradelph makes the transition to *anterior duplicity*. The appendix has but to be more equally proportioned to the chief body, and a completely double monster is formed. The best example of this occurred in the person of a certain Lazarus Colloredo, who lived for some length of time. His portrait is given by Bartholinus.

This very peculiar appendix never took food, nor had it evacuations of fæces. But the organic and the animal life appeared to be very well developed, as its cutaneous exhalation, its movements of different parts of its body, and the fact of its sleeping, showed.

The common character, by which this whole class of heteradelphs is distinguished, consists in the comparatively smaller size, and, in general, the defective developement, of the part which is termed the parasite. Imagine this difference removed by the fuller developement of the parasite, by its obtaining all its own organic apparatus, and by its growing *pari passu* with the other, and an exact idea of complete duplicity will be formed. It will be observed also, that in the several members of this class there is a regularly graduated series, from those in which the superfluous part is only an ill-developed limb, to those in which the parasite differs from the chief in nothing but its inferior size and its dependence for nutrition. The cases of the last kind are, however, rare. I know but three, of which that of the said Lazarus Colloredo, described by Bartholinus, is the most remarkable. Much more commonly the parasite, even when it possesses its full numerical complement of parts, bears many signs of defective developement; it is hare-lipped, or a cyclops, or has *atresia ani*, or some other malformation from arrest of developement. All this seems to me to prove, that in heteradelphs there are always the rudiments of two bodies, though one or both may be defective.

The beings thus formed have rarely lived many years after birth, and the histories of the few that have survived are, for the most part, well known in the records of medicine. Perhaps the most remarkable is that of the Chinese A-ke, of whom and his parasite little models are to be found in most of the anatomical museums of Europe. The parasite's life is, in general, only vegetative. In one of the three cases, indeed, in which it possessed all the constituent parts of a body, it moved its limbs, and appeared to have its own sensations; but in the others, less perfectly formed, even these signs of individual life were absent; and in only one, that of the Chinese A-ke, had the man who bore the parasite any voluntary power over its limbs. The nutrition of the parasite appears to depend entirely on the body to which it is fixed, and through which it both receives its nutritive materials and discharges its excretions. The one increases and decreases in size with the other; and, of course, the parasite dies with the individual to which it is attached. The influence which, in its turn, it exercises on its supporter is not always important. In the heteradelphs that die early, death commonly ensues from the malformation of the main body; if they survive, the parasite seems to do harm only, as an ordinary tumour would, by its weight, and by abstracting a certain amount of nourishment, so that those who, thus burdened, have grown up to childhood or manhood have usually been thin and delicate, like men subject to some unnatural waste. But, nevertheless, it will always be better to tolerate this evil than to risk an operation of removal, when the results of all the examinations yet made prove that the parasite is deeply and by important organs connected with its supporter. The only exception which I know to the correctness of my opinion is the case in which Mr. Blizard removed, with complete success, from the sacrum of a child, a congenital tumour, which seems to have been a *parasite*.

III. *Double Monsters.*

1. *Anterior duplicity.*

It has been already said that some of the rarer kinds of *heteradelphia* approximate closely to the double monsters. In all the cases that stand nearest to the transition, the parasite has been found adherent to the epigastric region; and the kind of duplicity which is most closely related to them, is therefore that in which the two bodies adhere by their anterior surfaces, or what we call *anterior duplicity*.

The most complete examples of duplicity yet known are found in this class, whose distinctive characters are, that two bodies, in a state of nearly equal developement, are placed exactly opposite to one another, with their sterna connected together, and with their abdominal cavities either partially or completely coalesced. Here, however, as in all the other classes, examples are found of gradations towards a state of singleness. For instance, the upper parts of the body being completely double, the lower are united, so that there are but three limbs, or only two lower or posterior limbs. And, in like manner, although in many cases the bodies are alike in size and other characters, yet there are many more in which one has so far surpassed the other, both in size and in stage of developement, as completely to fill up the series between this class and the decided heteradelphs. Whilst in the latter case we find close approximations to duplicity, there are even among the most perfect double monsters peculiarities which constantly recall to mind the parasitic attachment of the heteradelphs.

With this nearly perfect external duplicity there sometimes, but not always, corresponds an equal duplicity of organs. The umbilical cord may be single (Parsons, Otto), notwithstanding the heart is perfectly double. The two umbilical arteries belong but to one child; the umbilical vein bifurcates and enters both bodies. In another case (Cruveilhier), the single umbilical cord had two veins and four arteries, and the heart was externally single, and in its internal parts imperfectly double. In a third double monster (Otto), the umbilical cord had five vessels, two umbilical veins, and three arteries, and in this there were two hearts. In a fourth double monster the heart and umbilical cord were single. The bond of union, as far as the skeleton is concerned, is commonly a tough fibrous connection between the lower extremities of the sterna and the ensiform cartilages, which are set directly opposite to one another.

The rest of the sterna and the ribs are usually distinct, and the thoracic cavities are thereby separated. In this case there are commonly two separate and perfect hearts; but in the cases in which the sterna are more completely fused, or (as happened in one case) entirely absent (*Comm. Litt. Norimberg.*), only a single heart, or one partially double, with, for instance, two ventricles and four auricles, or otherwise malformed, is found. But it is particularly remarkable that in these, as in all other kinds of double monsters, there is no constant relation whatever between the respective states of the external and the internal organs, for the condition of the two digestive canals, even in those which are externally almost alike, is subject to still greater varieties than the condition of the heart. The abdominal organs are always in some degree connected; — the two livers are usually continuous.

A spleen, pancreas, and stomach are commonly found in each body, and each stomach has its own duodenum, which, after some length (being continued into the jejunum) unites with the other to form a single tract of small intestine, which again divides into two canals, leading respectively to the large intestine of each body. The lungs, the urinary, and the genital systems are always double. The most remarkable example of this class was the well-known Siamese twins. When exhibited, they were not exactly opposite to each other, but stood side by side, or, rather, obliquely one by the other; but this position, there can be little doubt, was acquired by the attempts which they had instinctively made to separate from each other in walking, or in lying and sitting down, and by the extension they had thus effected in their bond of union, which was considerably more slender than in any other yet described. It was quite impossible for them to remain always face to face; therefore their bodies acquired an oblique direction, in which they also moved. The consequence of this was, that the right limbs of the one and the left of the other individual were the principal organs of movement; and that the intermediate limbs, that is to say, the left of the one and the right of the other, remained merely passive (Dubois). The one individual was stronger than the other, and seemed to overrule him. But, nevertheless, in organic and animal relation of life they seemed to be independent of each other. Each had his own circulation of blood, his own respiration, and digestive functions. There did not seem to be a large anastomosis of vessels between the two bodies. But, by analogy with the foresaid cases, we may conclude that these twins are connected by the ends of their sterna, and by some of their abdominal organs. As a proof of this connection, may be adduced the result of the observations of Mr. Mayo, communicated at the *Conversazione of the College of Physicians March* 8th, 1831, that when either of the youths coughed, the bond of union swelled up in its whole length, proving that they had but one peritoneal cavity, of which a transverse prolongation passed through the connecting medium. And, therefore, I should conclude, that an attempt at separation could not be made with probability of success. The probability of having to cut through a piece of liver, or a peritoneal canal, must render an operation unwarrantable, unless, indeed, after the death of one of the bodies during the healthy state of the other. The case reported by König has scarcely authority enough to support a contrary opinion.

2. *Lateral duplicity.*

The varieties of form in anteriorly duplex monsters are closely limited by the partial nature of the union of the sterna and the nearly complete distinctness of the thoracic cavities, and hence of the whole upper part of the body. In the next class, which I call *lateral duplicity*, there is no such limit; and between the highest degree of duplicity found in it and the lowest, or that in which the duplicity is most nearly reduced to singleness, there is a far more numerous series of intermediate forms than in any other of the types of double monsters. In lateral duplicity, the two bodies are not set opposite to one another, but are turned sideways from one another. They have a common thoracic cavity, for the formation of which (at least, in the highest degree of duplicity,) the right ribs of one body, and the left of the other, proceed towards the anterior and posterior aspects, and are there connected with an anterior and posterior sternum. The best idea of the construction of this osseous fabric may be formed by supposing the two complete chests of two bodies to be set one against the other, and that then the anterior extremities of the right ribs of the right body, and those of the left ribs of the left body, unite with one sternum and pull it forwards, while, in the same manner, the left ribs of the right body, and the right of the left, unite on the posterior aspect with the other sternum, and carry it backwards. The consequence is, that the two vertebral columns are turned away from one another, and that the parts above and below the thorax are double. By the formation of this common thorax, the *lateral* is distinguished from the *anterior duplicity*, in which the thoraces are commonly connected only by the points of the sterna, and, as to their cavities, are separate. And with these differences of external construction, others not less important, of internal arrangement, coincide, which fully justify the separation of the two forms, however similar the external appearances of many of the examples of either may be.

The numerous varieties of lateral duplicity may be divided into two principal sets. The first begins with the complete duplicity of the whole body, and ends with its perfect singleness; in the second, the duplicity of the body remains, but the head gradually becomes single. The forms included herein, of which I have given ample accounts elsewhere, may be briefly summed up as follows.

1. Complete duplicity: — all the external parts and sometimes the abdominal and pelvic viscera double, — one common double-sized thoracic cavity, formed in the manner just described, and containing four lungs, and (in all cases with which I have been acquainted) only one heart. The examples of this form are very numerous, and are to be met with in all the large museums of Europe.

2. In the examples of this second group, which exhibits the first step towards singleness, one of the sterna may be traced in a succession of specimens, becoming gradually narrower, and permitting a closer approximation of the two corresponding upper extremities, till, in some examples, they are completely united, and there are found only three limbs above, with three or four below. The two juxtaposed scapulæ, for example, are merged into one, or they remain separate, but have only one humerus between them, and this splits below, to articulate with two fore-arms; or there is but one fore-arm, and this bears supernumerary fingers. In short by a great variety of modes there is a general tendency towards union of two of the upper extremities.

3. In the third group we have a repetition of the same series of changes in the lower limbs, as in the second was traced in the upper; here, as there, presenting numerous varieties, in the last and lowest of which only three lower limbs, and the third of these ill-formed, are found.

4. The third limb has now gradually disappeared, and, with a complete duplicity above the pelvis, there are but two limbs below it, and these well formed. In this class is placed, with many others, the *Ritta-Christina* monster, described by Serres, which lived to eight months, and the still more remarkable example mentioned by Buchanan, of a two-headed man, 28 years old, who lived in the reign of James III. of Scotland.

5. The union proceeding, and this simplicity of the lower part of the body being retained, examples come next in which the upper parts also are united; the two superfluous upper limbs being united into one, presenting a single upper-arm, with a double fore-arm and hand, or a single upper-arm, fore-arm, and hand with ten fingers, or only a mal-formed limb, or a mere projection, occupying the place of the superfluous limbs.

6. Even this last indication of duplicity of the upper parts ceases, a scapula only remains, or this also is absent; and next, one of the sterna having disappeared, and the vertebral columns having been connected on the corresponding side by their respective ribs united into single arches, these now become gradually shorter, and the columns approach each other more and more nearly, till they are connected by only a cartilaginous substance in the place of ribs, or are at some part fused together.

7. In this next group both the upper and lower parts of the body are single; the vertebral column is single below the cervical region, or exhibits only a trace of duplicity (to which something similar is often presented by the sternum), but at the cervical region becomes double, and on each portion bears a head. Of this also I have published many examples.

8. In the eighth group the extent of that cervical part of the column which is double becomes less and less.

9. In the ninth group, the two heads are seated on an apparently single neck, in which all the cervical vertebræ are single, or only bear traces of duplicity, except the first two, or the first alone.

10. Hitherto the duplicity of the head was perfect; in this group the two heads also begin to coalesce, and, in a considerable number of cases, gradations are traced in which the adjacent ears are very closely approximated, and the heads are united behind. Then there are cases in which one ear only is placed between the adjacent surfaces of the two heads, and this disappears gradually, and at last totally. Next in order are the cases in which the adjacent ears being lost, the two adjacent and middle eyes first become very close, and then occupying one orbit finally coalesce. Next come those cases in which there is such a union of the heads, that the two upper jaws are articulated with one lower jaw; and, lastly, those in which the head is doubled only in individual parts or in which

there is one perfect heart, with some imperfect part or parts of another attached to it.

11. The eleventh group of this division includes the cases of lateral duplicity, in which the body is single in the middle, but doubled above and below (or in brutes anteriorly and posteriorly). In these, which are of rarer kinds, a single neck bears two more or less completely separated heads. The vertebral column is for a considerable length single, but at its lower part again divides, and bears two sets of lower extremities.

12. In the twelfth group the body is single above and doubled below.

13. In this there is a tendency towards singleness, or even complete singleness, of the head, but all parts of the trunk and all the limbs are doubled, an arrangement by which, as already stated, these form a series entirely distinct from the rest. In some of these cases the two heads are found coalesced below; in others, to which the name of *janiceps* has been given, one face is directed backwards and the other forwards, the remainders of the two heads being merged into one; in others, one face is *perfectly*, the other very *deficiently*, developed; in others there are only the indistinct traces of a second head presented in the existence of one or two ears on the posterior aspect of the more perfect one; in others, this trace of duplicity is still less evident; and, lastly, in the remainder of the group, it is entirely lost, and one head only, which may be well or ill formed, is found upon the double body.

3. *Inferior duplicity.*

My third division of double monsters includes the cases in which there are two complete bodies with the lower portions of their respective trunks united, so that there is a head with upper extremities both above and below (the bodies being placed in the same straight line) and on either side of the part at which they meet two lower limbs. One may best conceive this arrangement by supposing two children stuck together by their buttocks, and so fixed with wide-spreading lower limbs, as may be seen in *fig.* 146. of the second volume of this Cyclopædia. A common body is thus formed with a head at each end, with two upper limbs both above and below, and with two lower limbs, one belonging to each fœtus on the right and two on the left of the united portions. A few cases only of this remarkable monstrosity are recorded; and in these the duplicity was not always complete, but exhibited in some the same tendency towards singleness as was noticed in the others. Thus in some there were but three lower extremities; in others there were but two, or two with a third ill-developed on the other side: and, again, in other groups there were those which have a perfect head at one end of the trunk, but an imperfect one or none at all at the other.

These monsters have been known to live a considerable time, their capacity for life being probably owing to the separation of the hearts and the absence of malformation in the more important organs of the body. The umbilical cord is single, and never has a double set of vessels; an apparent proof (confirmed by similar examples in other classes) that the one body is not formed of the materials of two; a conclusion which is supported by the coincident singleness of the anus and urinary bladder, and the union of the intestinal canals.

4. *Posterior duplicity.*

The fourth chief form is *posterior duplicity*, in which two bodies are united by their backs, or a part of them. The union may be at the pelvis (which is most common), and occurred in the well-known Hungarian sisters, who lived to their twenty-second year; or at the back of the vertebral column, or at the back part of the heads.

5. *Superior duplicity.*

The fifth is the *superior duplicity*, in which the two children are connected by their skulls, the bones of which are united so as to form a single skull. In these also the place of union varies greatly. The frontal bone of one coalesces with the parietal or the occipital of the other, or the foreheads are attached to one another, or the side of one head to the front of the other. But all these are very rare, and of each kind only one or two examples can be found on record.

All these are true double monsters. Of *tripled-bodied monsters* but one instance is known in the human subject (*Atti dell' Academia de Cattania*, t. viii. p. 203., 1834).

To conclude the description of duplicity, those which occur in individual parts of the body, the rest being single, viz. in the head, chest, abdomen, and limbs, ought to be recorded; such as, for example, two mouths, supernumerary teeth and horns, two œsophagi or duodena, double hearts, or supernumerary cavities in one heart otherwise well formed, a double penis and urethra, a double clitoris, supernumerary breasts, kidneys, vertebræ, ribs, fingers, toes, or whole limbs. But for all these I refer to my monograph.

At present I prefer to give all those considerations upon the origin of double monsters, of which this highly interesting subject is capable. From all the facts I have published, I point out the following *generalisations*: —

The double monsters form collectively one class of organic beings, which, however different in their several degrees of malformation, may be arranged in one continued series. As the lowest degree of duplicity, may be mentioned that of a single part of the body; for example, a double or supernumerary finger; as the highest, a complete double monster with two heads, four upper and four lower limbs, and two trunks, such as the Siamese twins. And between these two extremes there are different forms of duplicity, which gradually run one into the other.

There is no positive or constant relation between the external and the internal organs as to their degrees or modes of duplicity. In the completest duplicity of the exterior, for example, the heart is often single, or even shows signs of having been arrested in its developement; and, on the other hand, in the more nearly single forms, the heart is usually either partially or completely double. The histories of the cases of anterior and lateral duplicity, which I have given in my monograph, furnish abundant proofs of this. Nor is there any closer relation between the condition of any other internal organ and that of the exterior, than there is between it and the heart; for in nearly complete external duplicity any of the internal organs may be single; when there are two trunks indeed, the urinary and genital organs are commonly double; but as for the stomach, the liver, and the lungs, the correspondence between them and external duplicity follows no other rule than that where there are two necks there are two tracheæ and two œsophagi, and as a consequence the lungs and stomach are also doubled. When in like manner the stomach is double, each has its spleen and pancreas; but the state of the liver is very variable; sometimes there are two, sometimes but one with a single or double gall-bladder; and these differences often occur in the same form of external duplicity.

Parts placed on the surface of the body are more liable to multiplication than the internal organs, and duplicity of a single part is therefore much less rare than the formation of a complete double body. The upper half of the body is more frequently doubled than the lower, probably in consequence of its earlier developement and the admitted preponderance of the upper parts of the body. The union of the two bodies takes place only between similar parts. The more each of the bodies is developed, the less is the bond of union between them, as the examples of the Siamese twins and the Hungarian sisters sufficiently prove. And with this law is connected another, namely, that the probability of growing up is greater in the same proportion as the bond of union is smaller, and the coincident fusion of internal organs less, as these two and other double monsters prove. So also the further the several organs are from the situation at which the bodies are united, the more perfect they are, — one body is almost always less developed than the other: in the heteradelphs this is always the case, and in others the difference between the two bodies, though less evident, is scarcely less constant than in them. There are not commonly any signs of a double monster having been at first two individuals. For except in the cases of posterior and superior duplicity, and some singular examples of attachment of the umbilical cord of one fœtus to the head or the body of the other, there is never more than one placenta and one cord, and the latter usually contains only a single set of vessels, which divide when they reach the abdomen. And even in the posterior and superior varieties of duplicity it is not yet certain that there are two placentæ; in some cases the placenta was positively single, and in the remainder it has very rarely been examined. A last general rule is that in double monsters the twins are of the same sex. There is no well proved exception to this important rule.

What explanation can be given, after all these facts, of the origin of double monsters? On this subject, three hypotheses ought to be mentioned: 1. The double monster has been supposed to have proceeded from two distinct embryos, which have become united in the course of development; 2. It has been held to have originated in a single germ, which has become double, or has been subdivided; and 3. The germ has been regarded as abnormally compound from the first, implying that the organs and parts composing the double monster are at once produced from this germ, without either separation or coalition of its parts other than belong to the natural process of developement. On the comparative merits of the first and second hypotheses, as parts of the general doctrine of monsters, one of the most interesting physiological discussions extant is recorded in the *Mémoires de l'Académie des Sciences de Paris*, between 1724 and 1743. The chief disputants were Lemery and Winslow; the contest lasted nineteen years; it engaged the attention of all anatomists, and called forth writings by Haller and a crowd of authors of less note, and was only terminated by the death of Lemery. Every argument that could be founded on the knowledge of those days was brought forward, and the subject was, for the time, utterly exhausted; but the facts accumulated in later years have furnished such volumes of additional evidence, that the same question, between original and acquired monstrosity, as far as it relates to double monsters, may even now claim to be discussed.

It is certain that two ova may be formed in one Graafian vesicle (Von Baer, Bischoff, Bidder). The equally well-known fact, that the common fowl sometimes produces double-yolked eggs, naturally led at one time to the opinion that the formation of double monsters might be attributed to the developement and subsequent union of the embryo in each yolk; an opinion which has been adopted by some on very insufficient grounds, as it does not appear to be warranted by any direct observations made upon the result of the incubation of double-yolked eggs, and is at variance with much of what is known of the structure and mode of union of the two embryos composing a double monster.*

* I have here made use of the words of Professor Allen Thompson, who, in a remarkable memoir upon *double monsters*, published July, 1844, in the *London and Edinburgh Monthly Journal*, fully entered into the topic, and illustrated the genesis of double monsters by some very interesting observations. I lament that he was not acquainted with my monograph upon the same subject, nor with the succinct account which Mr. Paget has given of it in the British and Foreign Medical Review for October, 1841. He would have found in it a great deal in corroboration of his own opinions, in which I universally agree with him.

C. F. Wolff has distinctly affirmed, that a double-yolked egg is equivalent to a double ovum; that the produce of its incubation would be twins; and that a double monster can only proceed from a single yolk containing a double germ. Examples of double embryos of birds sometimes occur at the full period of incubation, in which both are complete, and there is no union, excepting at the umbilicus. It is barely possible that each of these embryos may have been developed from a separate yolk, and that in the course of incubation the two yolks have come to coalesce, in consequence of external pressure, or other causes. Towards the conclusion of the period of incubation, when the yolk usually enters the abdomen of the fœtus, we may suppose, in the case before us, a partial entrance of the common yolk into the abdomen of each embryo, and thus, upon the subsequent contraction of the umbilical aperture, the union of the two embryos may be effected. We learn, from the accurately-detailed observation of C. F. Wolff, previously referred to in my monograph, that two completely separate fœtuses may be formed in the bird's egg upon a single yolk, and within a single germinal and vascular area. The egg, in this instance, had been incubated six days, and both the embryos were at once so complete and so distinct, that there is no reason to believe they would have been united till the period when the entrance of the yolk into the abdomen of both, and the contraction of the umbilical apertures, had brought them together.

In a dozen double-yolked eggs, which Prof. Allen Thompson brought to incubation, he never succeeded in obtaining a double monster, nor even two embryos, at the full period, from any of them. In several instances he found that one yolk only had been productive.

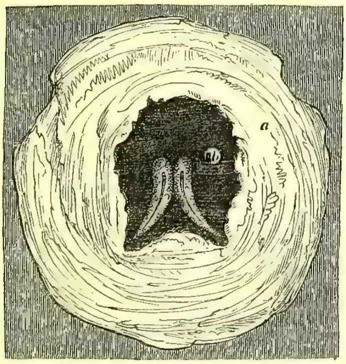
All this proves that such double-yolked eggs may produce twins, but that the formation of a double monster is not dependent on them. It is highly probable that in the same manner, in Mammalia, the arrival in the uterus of two impregnated ova, in close proximity with one another, will be attended with the production, not of a double monster, but of twins.

The complete fusion of these twins seems to me quite impossible. One of my chief arguments against the hypothesis of fusion of originally separate germs is the important fact, which I derive from my own investigations and from those of others, that double monsters form one series, among whose several members the degrees and modes of deviation from singleness gradually increase, and pass, without one abrupt step, from the addition of a single ill-developed limb to the nearly complete formation of two perfect beings. Now if this be true, no hypothesis can be acceptable if it do not plausibly explain the origin of the whole series of double monsters, or if, though it may suffice to explain the facts in one part of the series, those in another part are opposed to it. And here is a fair objection against the hypothesis of fusion of two originally perfect and separate embryos. Grant that we might explain by it the formation of several of the more perfect instances of duplicity; still, if the same hypothesis is altogether opposed by the simpler forms of duplicity, it is surely not tenable. For example, it cannot account for the existence on a child's sacrum of a shapeless mass, containing an isolated portion of intestine, as in Mr. Hanley's case. And still less can it explain the existence of a superfluous limb; for the limbs are mere off-shoots, and are produced at so late a period, that if we could imagine two embryos to come in contact by their shoulders or pelvis, and a fusion of those parts to take place, we should still have to explain how one of them, leaving only an arm or a leg behind him, could for the rest of his substance, head, trunk, and all, wholly disappear.

It was a main objection against the doctrine of Lemery, that if two germs came in contact by accident (as he supposed), they could not exhibit any regularity in their mode of attachment, but faces would be forced into chests, abdomens into spines, and so on. The moderns, who adopt the same hypothesis, suppose that the ova come in contact not by accident, but by an *attraction de soi pour soi,* of which the influence is, that the two ova being by accident set face to face or back to back, or in any other way *similia similibus,* will be drawn to each other, and will unite by similar parts. But, with all respect for the authority of M. Geoffroy St. Hilaire and his disciples (as Mr. Paget elegantly said in his abstract of my monograph upon double monsters), who regard this as "la règle suprême de tous les arrangements et de toutes les modifications organiques chez les êtres composés," I confess that I can find no good evidence that such an attraction exists. I can see in it nothing more than a very happy expression of a fact, which it in no wise explains. The extraordinary notion of MM. Delpech and Coste, that such an attraction may be the result of electric currents, is certainly no evidence of its existence, this being entirely imaginary. And the reasoning in its favour seems no better than the facts, for I can find nothing but this kind of circle: monsters adhere by similar parts, therefore there is an attraction *de soi pour soi;* there is then such an attraction, and therefore double monsters so adhere. I believe, therefore, that such an attraction is hypothetical; and if it be so, surely the hypothesis which involves it and an accident as essential elements is less probable, as well as less sufficient, than that which I maintain. It is scarcely better than Lemery's, of mere accident; for it requires not only the accident of a particular position of the ova, but that of their being of the same sex, which has been said previously to be the general rule for double monsters. After all this, we conclude with the words of the learned Wolff, published in 1773: — "Patet, igitur, monstra composita non sic oriri, ut aliquando duo separati integri embryones fuerint, qui dein contingentes et compressi, partibus eorum nonnullis destructis, aliis coalitis et commixtis, concrescerent in unum novum compositum corpus; ea vero, quæ vel defectu partium vel insolita structura monstra sunt, non ita fieri ut prius integri et naturales embryones fuerint, qui deinde per causas accidentales ad generationem non pertinentes mutilati vel transmutati fuerint; sed necesse esse, ut utraque monstrorum genera a primis suis initiis jam ejusmodi monstra fuerint."

If we are right in not admitting the existence and the fusion of two distinct germs, we necessarily adopt the opinion that only one germ has been formed, and that in this excess of formative power lies the cause and origin of every monstrous duplicity. Mr. Allan Thompson demonstrated, in coincidence with Wolff, Von Baer, and Reichert, as may be seen in the wood-cut (*fig.* 629.), that

Fig. 629.



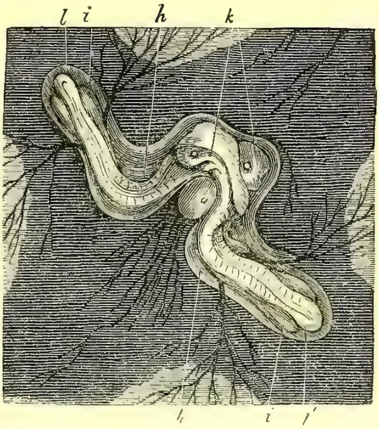
From a fowl's egg after sixteen or eighteen hours' incubation. Magnified four times.

a, the germinal area of the cicatricula; *b*, the transparent area, containing two primitive traces of embryos; *c c*, primitive grooves of the double embryonic trace, on each side of which are seen the laminæ dorsales.

(*After A. Thompson.*)

upon one yolk, and in one germinal membrane or blastodermatic vesicle, there may be formed, in birds, two primitive grooves, which, in their ulterior increment, shall probably form a double monster, as may be seen in a goose's egg, after five days' incubation, represented after Allan Thompson, in *fig.* 630. By the formation of such a double primitive groove in a single ovum, we may explain the origin of the principal types of double monsters; and on this point a recent observation of Valentin seems particularly worthy of notice, viz. that in which an injury, inflicted on the caudal extremity of an embryo on the second day, was found, on the fifth, to have produced the rudiments of a double pelvis and four inferior extremities. But if we admit this cause for those large and principal types, we must acknowledge that it is insufficient for the heteradelphs, and for all those cases in which, the body remaining single, some parts are

Fig. 630.



Double embryo removed from a goose's egg after five days' incubation. Magnified four times.

g, the common heart; *h*, rudiments of the superior, *i*, of the inferior extremities; *k*, the common cephalic fold of the amnios; *l*, the caudal folds.

(*After A. Thompson.*)

double. For these the excess of formative power is the only explanation we can give. We understand, under this name, not the *nisus formativus* of the ancient physiologists, working as a *Deus ex machina*, but the physical and vital *metamorphoses materiæ*, to which the formation of a new being ought to be attributed. Those who are fond of the modern nomenclature may name it, if it pleases them, *typical* or *organic power*. But enough, we admit such a power, of whatever name it may be, and contend further, that different degrees or quantities of excess lie at the origin of all the cases of double monsters, the degree of excess determining in each the degree of duplicity. If a certain excess of power be admitted capable of producing any one case of duplicity, other amounts of excess may be believed capable of producing all the other cases which differ from it only in degree; and I meant to have proved, in my monograph, and in the succinct survey I have given of double monsters in this Article, that all double monsters may be referred to differences in degree of deviation from the normal singleness.

But in many double monsters we see excess in one part and defect in another, so that we must suppose, in our hypothesis, that in these cases the power, more or less excessive in quantity, is also wrongly distributed. Nor is this inconceivable; for since, in the normal developemental power, we must imagine at least two elements, *quantity* and *distribution*, and must acknowledge that, for the attainment of a perfect result, the quantity must be distributed in definite proportions to each part, so it is not improbable that, in certain circumstances of fault in the ovum, a normal or an excessive power may be distributed disproportionately in the several parts.

To sum up, therefore, our reasons for rejecting the hypothesis of fusion of ova in favour of that of excess or irregular distribution of developemental power, for preferring to regard them as examples rather of singleness tending to duplicity than of duplicity tending to singleness, are briefly these: that it is probable that the whole class of monsters by excess owe their origin to different degrees of one common fault, and consequently that the explanation of their origin ought to be the same for all; that no kind of fusion can account for the production of supernumerary individual organs, the rest of the body being single; but that it is not impossible that excess of power in the ovum, which all admit can alone explain the lower degrees of duplicity, may, in proportionally higher degrees, perhaps by the formation of two primitive grooves, produce the more complete double monsters, or even two such separate individuals as are sometimes found within a single amnion.

Bibliography. — On account of the length of this Article, and the great number of books upon the subject, I shall omit the Bibliography, and refer to the foot-notes as well as to the manuals of Meckel, Rokitansky, Geoffroy St. Hilaire, von Ammon, and my own, in which the bibliography is duly noticed.

(*W. Vrolik.*)

TESTICLE.—(Human Anatomy). Gr. ὄρχις; Latin, *Testis — Testiculus;* French, *Testicule*; German, *Hode;* Italian, *Testicolo*.

The testicle is the gland by which the semen or spermatic fluid is secreted. Two in number, and contained within the scrotum, these organs are suspended at a variable and unequal distance from the abdominal rings, one testicle, generally the left, hanging a little lower than the other. This arrangement prevents collision between these organs when the thighs are suddenly approximated; one testicle slipping above the other, and thus eluding violence. In cases of transposition of the viscera and blood-vessels, it has been observed that the right testicle hangs lower than the left.

The shape of the testicle of an adult is that of an oval with flattened sides. The organ has two extremities, an antero-superior, and a postero-inferior; and two lateral surfaces. Its position in relation to the body is rather oblique, its long axis or antero-posterior diameter passing from above downwards and a little inwards. Its edges and sides are convex. Its upper extremity is rounded and capped by the epididymis, which rises above the body of the gland like the crest on a helmet. According to Cruveilhier the testicle measures two inches in length, one inch in breadth, and eight lines in thickness. Sir Astley Cooper makes its long diameter two inches; its transverse, an inch and a half; and its lateral, one inch and one eighth. I have found the mean dimensions of the testicle to be one inch and three quarters in length, one inch and a quarter across or in breadth, and one inch in thickness or from side to side. Meckel states its average weight to be four drachms, and Sir A. Cooper about an ounce. I have found the mean of these two estimates, viz. six drachms, to be the ordinary weight of the sound testicle of a healthy adult.* There are few organs subject to greater variations in size and weight than the testicle, even in men of the same age and constitution. The testicles also of the same individual rarely agree, the volume and weight of the left being, in general, greater than those of the right. I weighed the testicles of six men, two of whom were killed by violence, and found the left gland heavier than the right in five; in neither of these instances, however, was the difference more than a drachm. The organ feels tense, compact, and slightly elastic. Its degree of consistence depends more on the tension of the tunica albuginea than on the proper substance of the gland. It is a good deal influenced by the quantity of seminal fluid contained in the tubular structure, and its state of activity or rest; the gland being tense and tumid when the organ is exercised and the tubuli are distended, and soft and flaccid, when they are empty and the gland inactive. The parts composing the testicle may be described under four heads: — 1. The protective parts or tunics; 2. The proper glandular or secreting structure; 3. The excretory parts; 4. The vessels and nerves.

1. *The Protective Parts or Tunics.* — *The Tunica Vaginalis.* — This is a delicate serous membrane in the form of a shut sac, which consists of two portions; an outer one, the *parietal*, which is free and loose; and an inner, reflected, *visceral* or testicular portion, which closely invests the gland. The two portions are connected and continuous with each other. The outer one loosely invests the whole of the testicle except its posterior edge and inferior extremity, parts where the membrane becomes attached to the gland. It is connected with the testicle at about five lines from the lower extremity, and the junction of the two portions is marked by a white and rather irregular line. The uncovered portion of the organ corresponds to the original attachment of the gubernaculum. On the inner side of the gland the membrane, after investing the lower part of the cord to a greater or less extent, is reflected to the epididymis just below its head, and to the posterior edge of the body of the testis, being there separated from the epididymis by the vas deferens and blood-vessels of the gland. On the outer side the membrane entirely covers and closely invests the epididymis, and forms a cul-de-sac, which isolates its middle from the posterior border of the testicle, and in cases of hydrocele is often distended into a pouch. At the bottom of this sac the tunica vaginalis on the two sides comes into close contact, and sometimes there is a communication at this spot between the two. The smooth and polished surface of the shut sac thus formed by the tunica vaginalis is lubri-

* This nearly accords with Krause's estimate (Müller's Archiv. 1837.) — who found the mean weight in five instances to be 354·4 grains, or five drachms, two scruples and fourteen grains.

cated by an albuminous fluid, having the ordinary properties of the secretions of the other serous membranes. The office of this membrane is to facilitate the movements of the gland, so as to enable it to elude pressure and escape violence.

In some adult subjects the tunica vaginalis, which was originally a process from the serous lining of the abdomen, still retains its connexion with that cavity. When the communication is free, the sac is very liable to receive a protrusion of some of the contents of the abdomen, and become the seat of congenital hernia. Sometimes the communication continues through a contracted tubular canal, which, though too narrow to admit the transit of any of the viscera, is open to the passage of fluid. In other cases the obliteration is partial, one or more isolated serous sacs being left along the cord. It more often happens, however, that after the upper aperture of this process has closed a considerable part of it below remains unobliterated, so that the tunica vaginalis extends for some distance upwards in front of the cord. Frequently, also, although the obliteration is complete, remains of the prolongation may still be found in the form of a slender whitish filament, or fibrous process, which is lost in the areolar tissue in the anterior part of the cord, but may sometimes be traced as far as the tunica vaginalis.

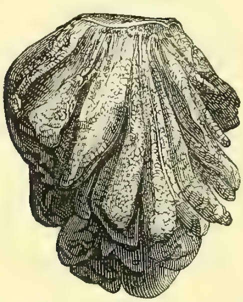
A small body of an irregular shape and variable size, and of a pale red or pinkish hue, is commonly found attached, often by a thin pedicle, either to the upper extremity of the testicle, or at the angle where the tunica vaginalis passes from the body of the gland to the epididymis. It is composed of a duplicature of this membrane, containing some fine areolar tissue and a number of small vessels. It occasionally contains a little fat. I have seen this little body in the testicle of the fœtus whilst in the abdomen, and, in early life, it is often of proportionally larger size, and of a deeper red colour than in the adult. It is quite distinct from the pedunculated cysts often found attached to the head of the epididymis. This little appendage to the tunica vaginalis seems to correspond with, and to be a type of, the remarkable omental process attached to the superior part of the testicle in the *Rodentia* and other animals. That it is an unimportant structure in the adult, is shown by its being frequently wanting. It may be of use, however, by slightly increasing the secernent serous surface.

The tunica Albuginea, or *Tunica Propria*, is a dense, tough, inelastic membrane, composed almost solely of white fibrous tissue, analogous to the sclerotic coat of the eye. It completely invests the body of the testicle, but not the epididymis. Its external surface is covered by the tunica vaginalis reflexa, to which it intimately adheres. This tunic is divisible into two layers, which can be separated only by a tedious dissection, but which in certain animals may be detached without difficulty. The branches of the spermatic artery and veins ramify in the substance of the tunica albuginea, in canals bearing in their arrangement some analogy to the sinuses of the dura mater, which membrane the outer layer is supposed to resemble. The smaller vessels are chiefly distributed on the inner layer, which owing to its vascularity has been compared to the pia mater investing the brain. At the postero-superior border of the testicle, and a little to its outer side, the tunica albuginea forms an internal projecting body or process, which lodges the blood-vessels and a portion of the glandular structure of the testicle, called the *rete testis*. This body is named, after the anatomist who first described it, the *Corpus Highmori*. It has since, however, been called by Sir A. Cooper the *mediastinum testis*, and he describes it as being formed by the tunica albuginea, which at that part is divisible into three layers. The first layer turns upon the spermatic cord, and unites with the sheath which covers the vessels. The second layer unites with a similar layer on the opposite side, and forms a thick substance, between the fibres of which interstices are left for blood-vessels and absorbents, whilst the internal layer, uniting with that on the opposite side, as well as with the preceding layer of the tunica albuginea, forms the process called mediastinum, which projects into the testicle between the tubuli, and it is in this substance that the seminal canals of the rete are placed. The mediastinum is therefore composed of two bodies; the upper placed towards the spermatic cord, the lower towards the centre of the testicle: in the upper are placed the blood-vessels; in the lower, the canals of the rete. Its length varies from six to eleven lines.

II. *Glandular or Secreting Structure.*— The glandular part of the testicle is very simple, and its tissue is more easily demonstrated than the structure of most other glands. It consists of numerous seminiferous vessels or tubes, supplied with blood-vessels, lymphatics, and nerves. Its colour is a greyish yellow or brown, more or less tinged with blood, and is paler in infants and old men than in adults. The tubes are collected into numerous lobes or lobules, invested by a fine areolar tissue, which, detached from the interior of the tunica albuginea, penetrates the gland, and sends out lateral processes forming septa, which separate and sustain the lobules. These septa at their origin partake of the fibrous character of the tunica albuginea, but as they converge towards the superior border of the testicle, occupied by the corpus Highmori, they become finer, and are gradually resolved into a delicate areolar tissue. The septa are traversed by numerous blood-vessels, which minutely divide in them before being distributed on the seminiferous tubes. Sir A. Cooper states, that the inverted portion of the tunica albuginea, forming the mediastinum testis, sends forth numerous ligamentous cords, some of which pass to the anterior edge of the testis; whilst others form shorter processes to support and invest the lobes, being met by similar ligamentous cords from the inner surface of the tunica albuginea. I have not been able to make out any such ligamentous processes passing into the substance of the testis, as are represented in Sir A. Cooper's work (part i. pl. 2. fig. 3), which I have no doubt is an exaggerated view of the preparation from which it was taken. The cords described appear to me to consist chiefly of blood-vessels supported by slight fibrous processes from the tunica albuginea and areolar tissue. In a well-injected testicle very little tissue of the nature of ligament can be found between the lobes. The secreting structure of the testicle, like the texture of many other glands does not possess much common sensibility. When exposed in disease it may be probed and injured with the forceps without pain.

Tubuli Seminiferi. — These tubes, which form by far the greatest part of the bulk of the glandular structure of the testicle, are very numerous, and radiate from all parts of the circumference of the organ towards the mediastinum, making numberless convolutions which progressively diminish as they approach the rete testis. Two or more of the tubuli, being collected together and invested by a common tunic of condensed areolar tissue, form a lobe or lobule of a conical form, its apex terminating at the corpus Highmori. The lobes thus formed are

Fig. 631.



The lobes attached to the mediastinum, but artificially separated from each other. (From a preparation in the Hunterian Museum, formerly in Sir A. Cooper's collection.)

not entirely distinct, but communicate with neighbouring lobes: the processes investing them are therefore incomplete, and the lobes cannot be separated from each other without division of some of the seminiferous tubuli. Krause estimates the number of the lobes as varying from 404 to 484.* The tubuli are of a white colour and uniform size, but their calibre differs in different subjects, and varies a good deal according to the age of the subject and the state of activity of the testicles, being larger in young adults and when distended with semen, than in old persons and when the gland is in a state of rest. The size of the ducts also often differs in the two testicles of the same subject. In general the calibre of the tubuli corresponds to the size of the testicle. Observers do not exactly agree in their estimates of the diameter of the tubuli. The average diameter of the uninjected canal is estimated by Müller at $\frac{1}{18}$ of a line; by Lauth* at $\frac{1}{185}$ of an inch. Krause found the tubuli, when filled with semen, to measure about $\frac{1}{12}$ of a line, and in old men and youths $\frac{1}{16}$. Huschke† estimated the ordinary thickness of the whole tube from $\frac{1}{13}$ to $\frac{1}{15}$ of a line, and that of the walls from $\frac{1}{100}$ to $\frac{1}{111}$. Owing to the stoutness of the basement membrane, the thickness of the walls of the tubes is considerable as compared with the secreting ducts of other glands, and this accounts for the tubes being able to resist the pressure of a column of mercury in injections. Monro reckoned the number of the seminiferous tubes at 300; Lauth made the average number 840, and he estimated the mean length of all the ducts united at 1750 feet. He found the individual ducts to vary in length, the mean being 25 inches. Krause estimated their entire length at 1015 feet. The membrane composing the tubuli is continuous with the mucous surface of the genito-urinary system. It is lined with epithelium, and the spermatozoa are developed from the epi-

Fig. 632.

Glandular structure of the testicle, displayed by mercurial injection. (After Lauth.)

a a a, glandular substance of the testicle subdivided into lobes, each lobe being composed of convoluted tubuli closely packed; *b*, rete testis; *c*, vasa efferentia; *d*, inflected part of the vasa efferentia forming the coni vasculosi; *e*, dilatations of the efferent vessels; *f*, body of the epididymis; *g*, tail of the epididymis; *h*, vasculum aberrans; *i*, inflected part of the vas deferens; *k*, straight part of the duct.

* Müller, Archiv. für Anatomie, 1837, s. 22.

* Mém. de la Société d'Hist. Nat. de Strasbourg, t. i.

† Encyclopédie Anatomique, t. v. p. 347.

thelial cells. There is no appearance of an intertubular substance; the ducts are merely connected by a loose network of vessels, and consequently readily admit of being separated and unravelled. The tubes, when successfully injected with quicksilver, form a beautiful anatomical preparation. Sir A. Cooper succeeded in filling the tubes with size injection; but he has not described the mode in which it was effected, and other anatomists have failed in similar attempts.*

When the tubuli seminiferi are unravelled, they are found to divide and form numerous anastamoses, which increase in frequency towards the circumference of the testicle. (See diagram, *fig.* 633. a^1 a^1). The tubuli thus form one vast network of communication, so that it is impossible to isolate completely either a duct or a lobule. The credit of making this interesting discovery of the anastamoses of the seminal tubes is due to Lauth. In only one instance did he succeed in finding a duct, terminating in a blind pouch, and this he regarded as exceptional. Blind ends have been found, however, more frequently by Krause. The anastamoses of the tubules have been observed in the rat and other animals as well as in man. The convolutions of the seminal tubes diminish in number as they approach the mediastinum, and cease altogether at a distance of from one to two lines, where two or more unite to form a single straight duct, termed *vas rectum*, which joins the rete testis at a right angle (a^2 a^2). The vasa recta are very slender, and easily give way when injected: their calibre, which is greater than that of the seminal tubes, is estimated by Lauth at $\frac{1}{108}$th

Fig. 633.

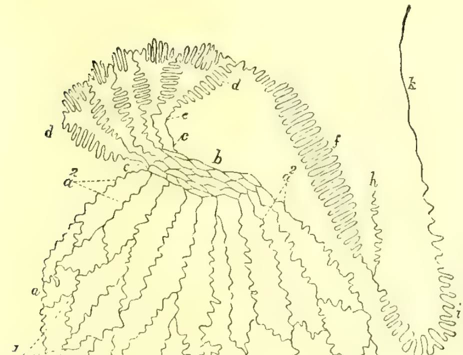


Diagram of the testicle. (*After Lauth.*)

a a a, tubuli; a^1 a^1, subdivisions and anastamoses of the tubuli; a^2 a^2, vasa recta.

The other references are the same as in *fig.* 632.

* Sir A. Cooper's beautiful preparations of the testicle are preserved in the Museum of the Royal College of Surgeons of England.

of an inch. Haller reckoned their number at twenty, which is, however, too few.

Rete Testis, as its name implies, consists of a plexus of seminal tubes, which occupies the corpus Highmori, or mediastinum testis. The vasa recta, after penetrating the walls of this body, terminate in from seven to thirteen vessels which, running parallel to each other in a waving course, and frequently dividing and anastomosing, form the *rete testis.* (b). Lauth found the mean diameter of the vessels of the rete in injected preparations $\frac{1}{72}$ of an inch. According to Prochaska, these vessels are supplied with valves, but such is not the case. Small dilatations, however, are often found in different parts of the plexus.

III. *The Excretory Parts.*—The *epididymis*, a continuation of the testicle, is a body of a crescentic form, divided into an anterior and upper extremity, called *head*, or *globus major*, which is firmly attached to the testicle; a middle part or *body*, which is less in size, and separated from the gland by a pouch of the tunica vaginalis; and a *tail* or *globus minor*, connected to the testicle by areolar tissue. The volume and weight of the epididymis vary in different subjects, but are proportionate to the size of the testicle. It is longer than the testicle, measuring about two inches in length and four or five lines in width. Its name (from ἐπὶ upon, and δίδυμος testis,) indicates its position, which is along the postero-superior border of the gland. The epididymis is chiefly made up of seminal canals connected and supported by a firm resisting areolar tissue. The ducts which spring from the upper part of the rete testis to form the epididymis are termed *vasa efferentia.* They are usually about twelve or fourteen in number, but vary from nine to thirty. The inflections of each of these efferent ducts are so arranged as to form in the head of the epididymis a series of elongated conical figures called *coni vasculosi.* These ducts, at their commencement, run straight for a distance of about one or two lines, when they form convolutions which become more numerous and close as the ducts recede from the testicle. Their length varies, the upper being the shortest. Lauth found their average length to be seven inches four lines, and calculating their number at thirteen, he makes the united length of the vasa efferentia nearly eight feet. He states that the efferent ducts diminish in size from their commencement to their termination in the canal of the epididymis, where they are less than the seminiferous ducts of the testicle. (*Fig.* 634.) As in the rete, round dilatations of variable size are often met with in these ducts. (*Fig.* 632., *e e.*) The efferent ducts, after forming the coni vasculosi, successively join a single duct, the canal of the epididymis, at irregular distances, the intermediate portions of the duct varying in length from half an inch to six inches. The efferent ducts are more slender than the canal of the epididymis, and frequently give way under the pressure of the column of mercury when injected. The body and tail of the epididymis are entirely made up of the convolutions of the single canal in which the

Fig. 634.

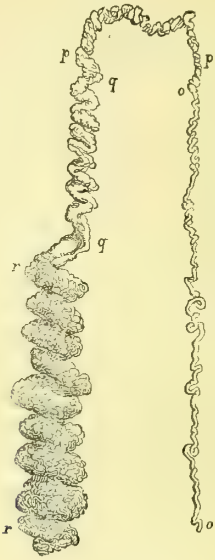
An efferent vessel and a portion of the head of the epididymis magnified, to show the progressive diminution of the canal of the cone, and the calibre of this vessel, in comparison with that of the canal of the epididymis.

c, vas deferens; *d*, inflected portion of the duct; *e e*, head of the epididymis. (*After Lauth.*)

vasa efferentia terminate, closely connected by areolar tissue. Monro described this canal as gradually increasing in size from the head to the tail, and he estimated its calibre about its middle at $\frac{1}{80}$ of an inch. Lauth states that its size is subject to great irregularities in different parts and in different subjects. This anatomist has particularly described the convolutions of this duct, and has shown that they are regularly arranged in four series, which successively increase in size; the first being the smallest, and the fourth the largest. The arrangement will be understood by reference to the subjoined figure. Monro estimated the length of the canal at thirty feet eleven inches. Lauth found its mean length to be nineteen feet four inches eight lines. The parietes of the canal are strong, and bear considerable resistance. The canal of the epididymis terminates in the excretory duct of the testicle, the vas deferens, and is usually contracted at the part where the two join, which accounts for the mercury when forced into the vas deferens being often arrested at this point. It was calculated by Monro that the semen, before arriving at the vas deferens traverses a tube forty-two feet in length. Lauth, however, makes the whole distance but little more than twenty-two feet.

Vasculum aberrans. — This name was given by Haller to a blind duct or cœcal appendage often found connected either to the epididymis or vas deferens. It is more commonly attached at the angle formed by the

Fig. 635.



Canal of the epididymis partly unravelled, to show the four series of inflections which the duct undergoes in the several divisions of the epididymis.

o, o, first series of inflections; *p, p*, second series; *q, q*, third series; *r, r*, fourth series. (*After Lauth*).

termination of the former in the latter. (*Figs.* 632., and 633, *h.*) It forms a convoluted duct as large as the canal of the epididymis, which is contracted at its insertion, and terminates in a blind and often dilated extremity. Sometimes after being dilated for a certain distance it diminishes, and becoming very minute, is lost in the areolar tissue of the cord. It usually passes up the cord for about two or three inches, but has been found to extend as far up as the brim of the pelvis. The length of this appendage when unravelled varies from one to twelve or fourteen inches. The vasculum aberrans is not constantly present; indeed, Monro found it only four times in sixteen; but I believe, with Lauth, that it exists more frequently. Occasionally there is more than one, and as many as three have been found both by Lauth and Sir A. Cooper. Hunter regarded these ducts as supernumerary vasa deferentia, of a nature similar to the double ureters.* Müller states that their office is evidently the secretion of a fluid which they pour into the epididymis.† We have no evidence, however, that the duct serves any particular office.

Vas deferens, — the excretory duct of the testicle, commences from the tail of the epididymis, and terminates in one of the ejaculatory canals behind the bladder, being in length from fifteen to sixteen inches. Arising

* Works by Palmer, vol. iv. p. 24.

† Physiology, trans. by Baly, vol. i. p. 45

from the contracted part of the canal of the epididymis at an acute angle, it ascends along the inner side of this body, from which it is separated by areolar tissue and the spermatic arteries and veins. A right or left testicle may thus always be distinguished by the circumstance that when the testicle is in position, the vas deferens is situated on the inner or mesial side of the organ. In this part of its course, for the distance of about an inch and a half, or more, the vas deferens forms numerous convolutions, (*figs.* 632., and 633, *i.*), which gradually cease as the duct mounts above the testicle. The inflected part of the vas deferens, when unravelled, was found by Lauth to measure six inches and a half. It afterwards takes a direct course (*k*) up the spermatic cord to the inguinal canal, passing behind and at a short distance from the spermatic arteries and veins. On entering the abdomen at the internal ring, it quits the spermatic vessels and descends into the pelvis, passing at first by the side of, and afterwards behind and below the bladder, on the inner side of the corresponding vesicula seminalis, the excretory duct of which it joins at an acute angle, to form the ejaculatory canal. The canal of the vas deferens is extremely fine, and its walls are nearly uniform in thickness until it reaches the vesicula seminalis. It is lined by a fine membrane of a mucous character, which is continuous with the urethra. This membrane forms longitudinal folds. The vas deferens is round and indurated, — harder than any other excretory duct in the body, by which character it is easily distinguished, when handled, from the other parts constituting the spermatic cord. Many anatomists have entertained the opinion that the parietes of this duct are muscular. It is distinctly so in the bear, bull, and other animals. On careful examination, however, of sections of the human vas deferens with the microscope, I could discover nothing more than simple fibrous tissue. Huschké makes three layers of fibres; two longitudinal, and one circular, situated between them; the latter being the thickest. The duct has an external investment of condensed areolar tissue.

IV. *The Vessels and Nerves.* — *Spermatic Vessels.* — The spermatic arteries, the chief vessels supplying the testicles, arise in pairs, at a very acute angle, from the fore-part of the aorta, immediately below the renal arteries. Their origin is subject to considerable varieties. The two seldom arise at the same level, and the right is often a branch of the right renal artery. Sometimes one or both come off from the superior mesenteric. Occasionally there are two spermatic arteries on one or both sides, arising in the regular way. All these deviations are more frequently met with on the left than on the right side of the body. Each artery pursues a tortuous course downwards and outwards, passing behind the peritoneum obliquely across the psoas muscle and ureter, to which, as well as to the surrounding areolar tissue, it gives off several branches. The artery then enters the inguinal canal through the internal ring, and emerging at the external, passes down the cord, being surrounded in its course by the spermatic veins. The further distribution of the artery is thus correctly described by Sir A. Cooper: "When the artery reaches from one to three inches from the epididymis, varying in different subjects, it divides into two branches, which descend to the testicle on its inner side, opposite to that on which the epididymis is placed; one passing on the anterior and upper, the other to the posterior and lower part of the testis. From the anterior branch the vessels of the epididymis arise: first, one which passes to its caput; secondly, another to its body, and, thirdly, one to its cauda and the first convolutions of the vas deferens, communicating freely with the deferential artery. The spermatic artery, after giving off branches to the epididymis, enters the testis, by penetrating the outer layer of the tunica albuginea; and dividing upon its vascular layer, they form an arch by their junction at the lower part of the testis, from which numerous vessels pass upwards; and then descending, they supply the lobes of the tubuli seminiferi. Besides this lower arch, there is another passing in the direction of the rete, extremely convoluted in its course, and forming an anastomosis between the principal branches." The testis receives a further supply of blood from another vessel, the artery of the vas deferens, or posterior spermatic artery, which arises from one of the vesical arteries, branches of the internal iliac. This artery divides into two sets of branches, one set descending to the vesicula seminalis and to the termination of the vas deferens; the other, ascending upon the vas deferens, runs in a serpentine direction upon the coat of that vessel, passing through the whole length of the spermatic cord; and when it reaches the cauda epididymis, it divides into two sets of branches, one advancing to unite with the spermatic artery to supply the testis and epididymis, the other passing backwards to the tunica vaginalis and cremaster.

The spermatic veins spring in three sets from the testicle, one from the rete and tubuli, and another from the vascular layer of the tunica albuginea, and a third from the lower extremity of the vas deferens. The veins of the testicle pass in three courses into the beginning of the spermatic cord; two of these quit the back of the testicle, one at its anterior and upper part, and a second at its centre; and these, after passing from two or three inches, become united into one. The other column accompanies the vas deferens. There is also a large vein, just above the testicle, which crosses to join the three columns. The veins of the epididymis are one from the caput, another from its body; one from its cauda, and another from its junction with the vas deferens, besides some small branches; they terminate in the veins of the spermatic cord. The veins, after quitting the testicle, become extremely tortuous, and frequently divide and inosculate in the cord, forming a plexus termed *vasa pampiniformia.* These communications cease as the veins approach the ring, which they enter, and ascending along with the psoas muscle in company with the spermatic artery, unite to form a single vein which usually terminates on the right side in the vena cava inferior, and on the left, in the renal vein; though this is subject to some variety. The left spermatic veins pass under the sigmoid flexure of the colon. Many anatomists speak of the spermatic veins as being destitute of valves, which they assign as one of the reasons for the occurrence of varicocele. I have several times injected these veins with alcohol, and on laying them open have observed valves in the larger vessels, and I have also found injections thrown into the veins arrested by the valves. They are seldom seen, however, very near the testicle, or in the smaller veins forming the plexus; nor have I observed them within the abdomen.

Absorbents. — The absorbent vessels of the testicle are very numerous, and arise from every part of its internal structure and coats. They unite to form four or five trunks, which ascend along the cord, and traverse the inguinal canal, without communicating with the glands in the groin, but pass upwards in front of the psoas muscle, behind the peritoneum, and terminate in the lumbar glands on the side of the aorta.

Nerves. — The nerves of the testicle are derived chiefly from the renal plexus, but partly also from the superior mesenteric and aortic plexuses. These nerves descend in company with the spermatic artery to the cord, where, being joined by branches from the hypogastric plexus, which pass along the vas deferens, they form together the spermatic plexus, the branches of which are intermingled with the vessels of the cord, and ultimately terminate in the substance of the testicle. A few twigs from the external spermatic nerve may also be traced to the coverings of the gland.

The Testicle in the Fœtus, and its Passage into the Scrotum. — The testicles are first developed and situated in the abdomen. They originate from the lower part of the corpora Wolffiana, and may be detected at an early period of fœtal existence immediately below the kidneys on the forepart of the psoas muscles, to which they are attached by a reflexion of peritoneum. This membrane closely invests the testicles in the same manner as it covers the other abdominal viscera. The position of the testicle in the abdomen is nearly the same as it maintains after its passage into the scrotum. The epididymis, however, is relatively of a larger size than in the adult, being about one-third that of the body of the organ. Attached to each testicle whilst in the abdomen is a peculiar body, which was termed by Mr. Hunter, who first described it, the *gubernaculum,* as it was supposed to serve as a guide to the testicle in its passage. It is a soft solid projecting body of a conical form, which varies somewhat in shape and size at different periods of transition of the testes, becoming shorter and thicker as the gland approaches the abdominal ring. It is situated in front of the psoas muscle, to which it is connected by a reflexion of peritoneum. Its upper part is attached to the inferior extremity of the testicle, lower end of the epididymis, and commencement of the vas deferens. The lower part of this process passes out of the abdomen at the abdominal ring, and diminishing in substance and spreading, terminates in three processes, each of which has a distinct attachment. The central part and bulk of the gubernaculum is composed of a soft, transparent, gelatinous substance, which, on examination by the microscope, is found to consist of nucleated cells, the primitive areolar tissue : this central mass is surrounded by a layer of well-developed muscular fibres, which may be distinguished by the naked eye, and which can be very distinctly recognised in the microscope to be composed of striped elementary fibres. These muscular fibres, which may be traced the whole way from the ring to the testicle, are surrounded by a layer of the soft elements of the areolar tissue, similar to that composing the central mass ; and, in the same way as the testicle, the whole process, except at its posterior part, is invested with peritoneum. On carefully laying open the inguinal canal, and gently drawing up the gubernaculum, the muscular fibres may be traced to the three processes, which are attached as follows : the external and broadest is connected to Poupart's ligament in the inguinal canal; the middle forms a lengthened band which escapes at the external abdominal ring, and passes to the bottom of the scrotum, where it joins the dartos ; the internal takes the direction inwards, and has a firm attachment to the os pubis and sheath of the rectus muscle. Besides these, a number of muscular fibres are reflected from the internal oblique on the front of the gubernaculum. It thus appears, that the attachments of the muscle of the gubernaculum, and those of the cremaster in the adult are exactly similar. I have succeeded in tracing out the former before the testicle has moved from its original position, at different stages of the process of transition, and immediately after its completion ; and of the identity of the two muscles no doubt can be entertained. Carus was of opinion that the cremaster does not exist before the transition of the testicle; but that it is formed mechanically, by the testicle pushing before it the lower fibres of the internal oblique, so as to form the loops of this muscle.* This view which has been adopted by M. Jules Cloquet, and after him by many of the anatomists of this country, is erroneous and inaccurate.†

The vessels of the testicle in the fœtus

* Compartive Anatomy, by Gore, vol. 2. p. 347.

† Vide Obervations on the Structure of the Gubernaculum, and on the Descent of the Testis in the Fœtus, by the author, in Lond. Medical Gazette, April 10. 1841, or in the Lancet, of the same date.

arise from the nearest largest trunks, and enter the substance of the gland at its posterior part. The artery of the vas deferens, from which the gubernaculum is chiefly supplied, is nearly as large as the spermatic. The long course taken by the arteries and veins of the testicle when in the scrotum is thus explained by the original site of the organ, to which circumstance must also be ascribed the sharp turn upwards of the vas deferens from the epididymis, the two being continuous in a direct line, whilst the testicle is in the abdomen.

Fig. 636.

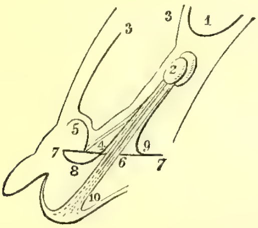


Diagram of the gubernaculum and testicle previous to its descent.

1, the kidney; 2, the testicle; 3, 3, the peritoneum; 4, vas deferens passing down into the pelvis by the side of the bladder; 5, the bladder; 6, the abdominal ring; 7, 7, Poupart's ligament; 8, pubic portion of the cremaster; 9, fibres of the cremaster arising from Poupart's ligament; 10, portion of the gubernaculum attached to the bottom of the scrotum.

Between the fifth and sixth month of fœtal existence, sometimes later, the testicle begins to move from its situation near the kidney towards the ring, which it usually reaches about the seventh month. During the eighth month it generally traverses the inguinal canal, and by the end of the ninth arrives at the bottom of the scrotum, in which situation it is commonly found at birth. The testicle, both during its passage to the ring and through the inguinal canal, carries along with it its original peritoneal coat, adhering by the reflexion of this membrane, during the whole of its course to the parts behind, in the same manner as whilst situated below the kidney. The testicle therefore does not pass directly and abruptly into a pouch prepared to receive it, but carries the peritoneum with it, continuing to be connected to the parts behind by the reflexion of the membrane, between the folds of which the vessels and nerves join the gland. In the passage of the testicle from the abdomen to the bottom of the scrotum, the gubernaculum, including its peritoneal investment and muscular fibres, undergoes the same change as that which takes place in certain of the *rodentia* at the access of the season of sexual excitement; the muscle of the testicle is gradually everted, until, when the transition is completed, it forms a muscular envelope external to the process of peritoneum, which surrounds the gland and front of the cord. As the testicle approaches the bottom of the scrotum, the gubernaculum diminishes in size, owing to a change in the disposition of its areolar elements; the muscular fibres, however, undergo little or no diminution, and are very distinct around the tunica vaginalis in the recently descended testicle. The mass composing the central part of the gubernaculum which is so soft, lax, and yielding, as in every way to facilitate these changes, becomes gradually diffused, and after the arrival of the testicle in the scrotum, contributes to form the loose areolar tissue which afterwards exists so abundantly in this part; the middle attachment of the gubernaculum, which may be traced to the dartos at the bottom of the scrotum, gradually wastes away and soon becomes indistinct, though slight traces of this process often remain to the latest period of life. Thus, after death, in dragging the testicle of an adult out of the scrotum by pulling the cord, the lower part of the gland, which is uncovered by serous membrane, is often found connected to the bottom of the scrotum by a band of firm and dense areolar tissue, which requires division with the scalpel. This band is the remains of the middle attachment of the gubernaculum. In cases in which the testicle has been retained in the groin, I have traced a cord of dense tissue from the gland to the lower part of the scrotum. After the arrival of the testicle in the scrotum, the peritoneum with which it is closely invested, its original envelope, becomes the inner layer of the tunica vaginalis; whilst the pouch around, which is continuous with it, forms the outer layer, or vaginal sac. Immediately after the arrival of the testicle in the scrotum, this bag communicates with the abdomen, and in quadrupeds continues to do so during life; but in the human subject it soon begins to close, and when the fœtus is ushered into the world, the abdominal orifice is often shut, and the whole canal from the ring to the upper part of the gland is, in general, completely obliterated in the course of the first month after birth. The obliteration is effected by an intimate union of the surfaces of the serous membrane. It sometimes does not take place at all*, or is delayed or only partially com-

Fig. 637.

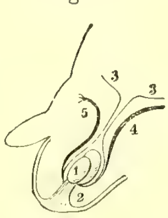


Diagram of the testicle immediately after its arrival in the scrotum, the cremaster being everted.

1, the testicle; 2, the shortened gubernaculum; 3, 3, the peritoneum; 4, portion of the cremaster arising from Poupart's ligament; 5 pubic portion of the muscle.

* The communication constantly remains open in quadrupeds, the chimpanzee, according to Professor

pleted. Congenital hernia, or hydrocele is the result of a failure in this process; and other forms of hydrocele are occasioned by imperfect obliteration of the canal.

Much difference of opinion exists as to the immediate cause of the transition of the testicle. Hunter, Meckel, and others came to the conclusion that the muscular fibres of the cremaster are insufficient to bring the testicle further than the abdominal ring and complete the passage. They were not, however, acquainted with the attachment of this muscle to the pubis external to the ring, or it would be difficult to understand why Mr. Hunter, after arriving at the conviction that the cremaster passes to the testicle whilst in the abdomen, chiefly from analogy, was not induced by the same process of reasoning to conclude, that a muscle capable of changing the position of the testicle in brute animals, would be adequate to accomplish the same office in the human fœtus. The necessity for some active agent to effect this change in the latter would appear to be greater even than in the lower animals, since, in the usual position of the fœtus in utero, the passage of the testicle is contrary to gravitation,* and unaided by the movements of respiration. Now, when we consider the attachments and connections of this muscle in the fœtus; the perfect development of its fibres, as ascertained by microscopical examination; and the circumstance that there are no other means, no other motive powers, by which this change can be effected, or in any way promoted, I think there is no reason to doubt that the cremaster executes the same office in the human embryo, as that which it undoubtedly performs in certain brute animals at a particular season. The fibres proceeding from Poupart's ligament, and the obliquus internus, tend to guide the gland into the inguinal canal; those attached to the os pubis to draw it outside the abdominal ring; and the process extending to the bottom of the scrotum, to direct it to its final destination. As the process approaches completion, the muscular fibres which perform so important a part in it gradually become everted, and acquire the new functions of elevating, supporting, and compressing the gland.

The Functions of the Testicle. — The sperm or fluid secreted by the testicle has been considered in the article (SEMEN). On surveying the structure of this gland, we cannot fail to remark the great extent of secreting surface afforded by the numerous, long, and tortuous tubuli, and the length and complexity of the excretory duct through which the seminal fluid has to pass. The extent of this duct is, indeed, so remarkable, that many physiologists have been led to suppose that the semen is further elaborated or perfected in its passage through the convolutions constituting the epididymis. An examination of the spermatic fluid taken from the testicle and its duct both in man and in the lower animals, under all circumstances and at all periods, and the varying state of the discharge in cases of spermatic fistula, leave little room to doubt that secretion takes place actively only during the periods of sexual excitement, or under the influence of sexual feelings and desires. From birth to the period of puberty the testicles remain small, and grow but little in proportion to other parts; but as the body, on the arrival of puberty, becomes stamped with the characters of the male sex, they rapidly enlarge, their glandular structure becomes much more developed, and, being excited, these organs begin to exercise the office of secretion, no spermatozoa being found in them until this period arrives. The age at which the testicles thus become developed varies in different climates, and in different constitutions, and is influenced by the mode of life and circumstances in which the individual is placed. The inhabitants of warm climates reach the age of puberty earlier than those of cold countries. In this part of Europe the change takes place from the age of fourteen to seventeen years, according to circumstances. Unlike the inferior animals, the testicles in man are ready at all seasons to perform their office. The desires subside, and the secretion of semen becomes languid as life advances, though they seldom cease entirely till the age of sixty-five or seventy. Indeed, I have several times discovered spermatozoa in the testicles of men upwards of seventy years of age, and once in the testicle of a tailor who died at the age of eighty-seven. There are instances on record of persons retaining the procreative faculty to the age of one hundred years; but in these cases, as in the well-known instance of old Parr, the general bodily powers were also preserved in a very extraordinary degree.*

"To the use of the sexual organs for the continuance of his race man is prompted by a powerful instinctive desire, which he shares with the lower animals. This instinct is excited by sensations, and these may either originate in the sexual organs themselves or may be excited through the organs of special sensation. Thus in man it is most powerfully aroused by impressions conveyed through the sight or the touch: in many other animals, the auditory and olfactive organs communicate impressions which have an equal power; and it is not improbable that in certain morbidly excited states of feeling, the same may be the case in ourselves. That local impres-

Owen, being the only brute animal in which the tunica vaginalis forms a shut sac.

* For this reason I have departed from the usual custom of English anatomists, and avoided describing the change in the position of the testicle, as *the descent.*

* Old Parr, who lived to the great age of 152, was dissected by the celebrated Harvey, and it is stated, "Genitalibus erat integris, neque retructo pene neque extenuato, neque scroto distento ramice aquoso ut in decrepitis solet, testiculis etiam integris et magnis." Bettus de Ortu et Natura Sanguinis, p. 320.

sions have also very powerful effect in exciting sexual desire must have been within the experience of almost every one; the fact is most remarkable, however, in cases of satyriasis; which disease is generally found to be connected with some obvious cause of irritation of the generative system, such as pruritus, active congestion," &c.*

The part of the brain which is the seat of the sexual appetite is supposed by the phrenologists to be the cerebellum, between which and the genital organs a close sympathy is said to exist. The grounds for this assumption, and the objections which have been fairly urged against it by sound physiologists, have been stated in a preceding article. (Nervous System, Physiology of, vol. iii. p. 782. s.) No doubt, however, can be entertained that the mind is intimately connected with the procreative faculty, and that the brain controls and animates the desire for sexual enjoyment. An affection of the brain, or the mind, as sudden disgust, arrests the secretion of the testicles and extinguishes all desire as quickly and effectually as a strong mental impression stops the secretion of the gastric juice, and takes away all appetite for food. The influence of the brain on the reproductive function is well illustrated by the occasional effects of injuries of the head. Hildanus mentions the case of a man accused of impotency by his wife, who sued for a divorce. Nothing external was defective; but the man stated that eight years previously he had received a blow on his head by a stick. From that period, "confitebatur penem erigi non posse."† Dr. Fisher relates the case of a gentleman who, while looking out of the window of a railway carriage, which at that moment encountered a violent collision, received a blow on the head and neck, by which he was stunned. On the second day after the accident he complained of a numbness in his right arm, and experienced difficulty in passing his urine. In the course of two weeks he was able to leave his bed, and walk in the street; but his vision was defective. Between the fourth and fifth week after his injury he made the discovery that he had lost the desire and physical power for sexual intercourse, and that no amorous sentiment, or the approach of a female could excite it. Under appropriate treatment the bladder gradually recovered its power, and his vision became perfect; but the numbness of the right arm continued, and the generative functions remained partially impaired. His mental powers, particularly his memory of events, were also for a time seriously affected.‡ Dr. Gall mentions that at Vienna he was consulted by two officers who had become impotent in consequence of blows from fire-arms which had grazed the napes of their necks. One of the officers recovered his powers by degrees, married, and became the father of several children.*

When treating of Atrophy of these glands, I shall have occasion to mention cases in which the genital function has been permanently annihilated, and complete wasting of the testicles has resulted from injuries of the head. In respect to the mode in which these organs are called into action, they bear considerable analogy to the lachrymal, salivary, and mammary glands, in which secretion is excited both by the influence of the mind and by mechanical contact or local irritation of the extremity of the excretory duct, the glans penis holding the same relation to the testicle as the mucous membrane of the mouth does to the salivary glands, or as the nipple does to the mamma.

The influence of the testicles and brain upon each other appears, as has been already observed, to be reciprocal; for not only may desire be aroused by local irritation and exciting the testicles to secrete, but the passion itself never arises when these glands are removed before puberty and is extinguished by their extirpation afterwards. Nothing, indeed, illustrates more forcibly the intimate relation which the functions of the testicles bear to the mind and character of the individual, and the general organisation of the body, than the effects of castration. When it is performed in early life, the changes characteristic of puberty never ensue. There is a deficiency of the beard; the muscles do not acquire the manly tone and vigour; the areolar and adipose tissues abound; the voice retains the high and clear tones of infancy; and the mind remains deficient in energy and strength. When the testicles are removed after the period of puberty, the eunuch loses in part, though not entirely, his former masculine character. His beard grows less abundantly; his voice becomes shrill; and there is diminished energy and vigour in all his sentiments and actions. These changes in the constitution, as well as the loss of the sexual instinct which occur in men thus degraded, do not immediately succeed the removal of the testicles, but take place gradually; and there are well-attested cases in which desire has been experienced, and connection with emission accomplished many months after the loss of these organs. This shows that the passion is not solely dependent on the secretion of semen, though it invariably declines when the power of procreation becomes lost. The emissions in such cases are imperfect and fruitless, consisting merely of the secretions of the vesiculæ seminales and prostrate. The testicles not being parts essential to life, are subject to different laws from those which regulate the actions of the vital organs. Their functions may be suspended, or they may remain in abeyance for an indefinite period without injury to the glands or any material effect on the constitution. In persons of

* Dr. Carpenter's Principles of Human Physiology, p. 619.

† Opera Observationum et Curationum Medico-Chirurgicarum, p. 574.

‡ Case by Dr. Fisher. American Journal of the Medical Sciences, Feb. 1839. p. 357.

* On the Functions of the Cerebellum, tr. by Combe, p. 46.

recluse and studious habits the functions of these organs often continue dormant for years. Like the mammæ in the unmarried female, though inactive, they remain sound and competent for secretion when duly excited and called upon to exercise their functions. It often happens that the passions are excited without an opportunity being afforded for their gratification. Under these circumstances the testicles become encumbered with secretion which would prove injurious to them were they not relieved by occasional nocturnal emission, or ejaculations of the semen under the influence of dreams during sleep, which appear to be a salutary provision to obviate the inconveniences which might result as well from ungratified desires as from an accumulation of semen in the ducts.

Envelopes of the testicle.—The *scrotum*, or pouch of integument containing the testicles, including the *dartos*, has already been described. (Article SCROTUM).

Superficial or external spermatic fascia. — Beneath the loose areolar tissue of the scrotum is situated a delicate layer of fascia, which is continuous with the superficial fascia of the lower part of the abdominal parietes, and, descending so as to form a sheath to the spermatic cord and an envelope to the testicle, becomes continuous behind with the superficial fascia of the perineum. This fascia is usually very thick and distinct in cases of large and old scrotal hernia.

Cremaster muscle — Directly beneath the superficial fascia is found the cremaster muscle (so named from *κρεμάω to suspend*), or, as it has been appropriately termed by Mr. Hunter, the *musculus testis*. (For description, vide, ABDOMEN, vol. i. p. 6.) The two attachments of this muscle, the external to Poupart's ligament, and the internal to the os pubis, correspond, as I have previously (p. 983.) shown, to those of the muscle of the gubernaculum, being indeed the same structure, with its relations altered. The actions of the cremaster, which, with a few exceptions, are involuntary, appear to be those of giving a tonic support to the testicles, retracting them to the abdominal rings, and compressing them during the sexual act. In some instances, in boys before the approach of puberty, this muscle has been capable of drawing the gland up into the inguinal canal. Persons are occasionally met with who possess a voluntary power over its actions in various degrees of perfection. Some are able to elevate the testicle on one side but not on the other, whilst others can retract both testicles to the abdominal rings, and retain them there at will. A very remarkable instance of the cremaster muscle being completely under the influence of volition is recorded by Mr. Hutchinson.*

Deep spermatic fascia. — The tunica vaginalis and spermatic cord are invested by a thin delicate fascia, which is situated beneath the cremaster muscle, and forms a common fibrous envelope to the testicle, and spermatic cord. It is attached to the back part of the gland. This membrane may be traced as a prolongation of the *fascia transversalis*, and is probably formed in the process of transition of the testicle from the abdomen to the scrotum.

The spermatic cord. — The parts composing the spermatic cord, are the vas deferens, the artery of the duct, the spermatic artery and veins, the lymphatic vessels, and the spermatic nerves. These parts are connected by loose areolar tissue. A fibro-cellular process, being the remains of the process of serous membrane originally connecting the tunica vaginalis with the peritoneum, may sometimes be perceived in the front part of the cord. The spermatic cord extends from the internal abdominal ring to the back part of the testicle. Its upper portion, therefore, lies in the inguinal canal. The coverings of the cord are the same as those of the testicle: viz., the integuments, superficial fascia, cremaster muscle, and deep spermatic fascia.

For COMPARATIVE ANATOMY, see the article ORGANS OF GENERATION.

ABNORMAL ANATOMY OF THE TESTICLE.— *Congenital imperfections and malformations.*— *Numerical excesses and defects.*— Cases of supernumerary testicles are mentioned in the writings of the old authors, and persons have been described with four or five of them, accompanied with a proportionate increase in the venereal appetite. Nearly all these cases are of a fabulous character. Such must be remarked of the case of *πεντόρχος*, or man with five testicles, mentioned by Schaarf*, and with that of a man with four testicles alluded to by Blegny.† Blasius, an old writer not unworthy of credit, has, however, given an account of the examination of a man, thirty years of age, and otherwise well formed, who had two testicles on the right side, of the same size and shape as that on the left, which is illustrated by a small engraved figure representing a distinct artery from the aorta, and vein from the vena cava proceeding to each of the two testicles on the right side.‡ This is the only case of supernumerary testicle recorded by the old authors, which has any semblance of authenticity. Neither Morgagni, Haller, nor Meckel met with a single example, and they questioned the existence of such a condition. Two cases have recently been recorded as examples of triple testicle, but they were not verified by examination after death. One is related by Blümener, an army surgeon, in Rust's Magazin für die Gesammte Heilkunde for 1824: the other by Dr. Macann, a British surgeon.§ An epiplocele, a fatty or fibrous tumour in the scrotum, or an encysted hydrocele of the cord,

* Practical Observations in Surgery, second edit. p. 186.

* Eph. Nat. Cur. Dec. 111. Ann. v. vi. Obs. 89. p. 175.

† Zodiaque Français, Ann. 11. Most of the reputed cases of *Triorchides* are quoted by Arnaud, in his Mémoires de Chirurgie. Mem. iii. part i.

‡ Ger. Blasius, Obs. Med. Anat. Obs. 20. p. 60.

§ Provincial Medical Journal, Nov. 5. 1842, p. 113.

might readily be mistaken for an additional testicle. Morgagni mentions that he was once deceived by a portion of omentum. In the pathological collection at St. Thomas's Hospital is preserved the testicle of the eccentric Dr. Monsey, who appeared during life to be supplied with three of these glands. The supposed additional testicle consists of an indurated fibrous tumour attached apparently to the tunica vaginalis.

Many instances of *monorchides*, or persons having only a single testicle are also mentioned by the old authors; but as the data are very imperfect, and as little was known respecting the transition of the testicle at the time these cases were recorded, they must be viewed with great suspicion. They were most probably cases in which one of the glands was either retained within the abdomen, or, from some cause had been completely atrophied. I know no satisfactory reason why a deficiency of one or both testicles should not occasionally occur without any other malformation; but they are anomalies of which there are few authentic examples in the annals of medical science. Mr. Paget has published the particulars of a case in which he believes one testicle was deficient at birth.* No account of the man is attached to the particulars of the dissection, and it is open to question whether the deficiency of the gland was not the result of atrophy. Dr. Fisher, of Boston †, has recorded a more satisfactory example of absence of both testicles. The deficiency was remarked from birth, and the subject of the malformation was regarded as a natural eunuch, and died at the age of forty-five.

Mr. Thurnham has published an account of the dissection of an infant who died at the age of four months. In addition to an atrophied condition of the right kidney, and a remarkable malformation of the ureters, it was found that neither of the testicles had descended. The right lay in the abdominal cavity, just above the inguinal canal. On the left side no testicle would appear to have been formed; the spermatic vessels on this side terminated in a little mass of fat; the vas deferens, however, was present, and was apparently as well developed as that of the perfect testicle.‡ A case of monstrosity is related by Dr. Friese in Casper's Wochenschrift.§ The child lived only half an hour: in addition to the absence of the external genital organs, there were neither testes, vasa deferentia, nor vesiculæ seminales. Cases, however, in which the whole of the genital apparatus is deficient or irregularly formed, do not come within the scope of this article. Geoffroy St. Hilaire has recorded a remarkable, and so far as I know, unique case of union of the testicles in the abdomen. ||

* London Medical Gazette, vol. xxviii. p. 817.

† American Journal of the American Sciences, vol. xxiii. p. 352.

‡ London Medical Gazette, vol. xx. p. 717.

§ Dec. 25. 1841. Quoted in the British and Foreign Medical Review for April 1842, p. 527.

|| Hist. des Anomal. de l'Organ. t. i. p. 542.

Deficiencies and imperfections of the vas deferens. — In Mr. Paget's case of supposed absence of the testicle it is stated, that the vas deferens terminated nearly opposite the external ring in a rounded cul-de-sac; and in Dr. Fisher's case of deficiency of both testicles, that the vasa deferentia, though properly formed and nearly of natural size, terminated in cul-de-sacs at the end of the cord. In the museum of St. Bartholomew's Hospital, there is a preparation taken from a man fifty years of age, who died of strangulated hernia. A piece of intestine was strictured by a band of adhesion connected with the mesentery, and the testicle was detained in the upper opening of the ring. On dissection of the parts, the vas deferens was found to terminate near the testicle in a cul-de-sac. The gland was very small, and its structure appeared granular like the undeveloped testicle of a youth. There was no trace of the epididymis. Mr. Hunter in dissecting a male subject found the vasa deferentia not only deficient near the testicles, but terminating below in a single irregularly formed vesicula seminalis, and having no communication with the urethra.* There are a few other cases on record, in which the vas deferens has been defective at the extremity which joins the ejaculatory canal. Thus, Tenon, in the dissection of an infant affected with extraversion of the bladder, found that the vasa deferentia terminated separately at the bottom of the pelvis, in two white tubercles: the scrotum, testes, and vesiculæ seminales were in a natural state.† But besides these imperfections at its two extremities, this duct has been found wanting throughout nearly its whole extent. Brugnoni mentions, that in dissecting the parts of generation in a robust man, from twenty-six to twenty-seven years of age, he found the right epididymis almost entirely absent, the only part remaining being the head, which formed nodules filled with semen. The rest of the epididymis and the vas deferens were wanting, without any mark of disease. The testicle was perfectly sound, and nearly of the same size as the left one. On examining the corresponding vesicula seminalis he found at its anterior extremity a portion of the canal of the vas deferens about an inch in length, and properly formed. The vesicula seminalis itself was flaccid and quite empty; whilst the left was full of semen. He remarks, that although this vicious conformation was according to all appearances congenital, nevertheless the vesicula seminalis and ejaculatory canal had preserved their natural cavities.‡ In a case related by Bosscha, the left vas deferens of a robust man terminated in a blind extremity near the testicle, the rest of the canal being wanting. There was the rudiment of a left vesicula seminalis in the

* Works by Palmer, vol iv. p. 23.

† Mém sur quelques Vices des Voies Urinaires, &c. n Mém. de l'Acad. Roy. des Sciences à Paris, 1761, p. 115.

‡ Observ. Anat. sur les Vesicules Seminales. Mém de l'Acad. Roy. des Sciences à Turin, 1786, and 1787, p. 625.

form of a blindly-ending canal running tortuously in the shape of the letter S. The left testicle was sound.*

Mr. Paget has happily explained the origin of these several defects in the vas deferens, by reference to the mode of development of the special organs of generation. He observes†, after Müller and Valentin, that, in the normal course of human development the proper genital organs are in either sex developed in two distinct pieces : namely, the part for the formation of the generative substance, the testicle or ovary, and the part for the conveyance of that substance out of the body, the seminal duct or ovi-duct. The testicle or ovary as the case may be, (and in their earliest periods they cannot be distinguished), is formed on the inner concave side of the corpus Wolffianum, and the seminal or ovi-duct, which is originally an isolated tube closed at both extremities, passes along the outer border of that body from the level of the formative organ above to the cloaca or common sinus of the urinary, genital, and digestive systems below. The perfection of development is attained only by the conducting tube acquiring its just connections at once with the formative organ, and, through the medium of the cloaca, with the exterior of the body. The sexual character is first established, when, in the male, the formative and conducting organs become connected by the development of intermediate tubes which constitute the epididymis ; or when in the female, a simple aperture is formed at the upper extremity of the conducting tube, and is placed closely adjacent to the formative organ. In both sexes alike, the lower extremities of the conducting tubes first open into the common cloaca, and subsequently, when that cavity is partitioned into bladder and rectum, or bladder, vagina, and rectum, they acquire in each their just connections, and become in the male the perfect vasa deferentia, and in the female the Fallopian tubes and uterus.

The inquiry is not without interest, what influence have these deficiencies and imperfections in the vas deferens on the evolution and subsequent condition of the testicle ? In the case of the adult which occurred at St. Bartholomew's Hospital, the testicle was small, and its structure appeared granular, like the undeveloped testicle of a youth, but as it had not descended into the scrotum, and was combined with hernia, there may have been other causes impeding its due evolution. In Mr. Hunter's case, the testicles which were in the scrotum were very sound. In the case of the man related by Brugnone, the testicle on the side corresponding to the defective vas deferens was perfectly sound, and nearly of the same size as the other. So also in Bosscha's case, it is stated, that the testicle was sound. Although either of these defects in the vas deferens renders the gland an useless organ, and if it occurred on both sides of the body, would necessarily cause impotency, these cases, nevertheless, tend to shew that the absence or imperfection of the excretory duct does not prevent the development of the testicle at the proper period, and has no direct influence in causing it to waste; and these inferences are fully confirmed by experiments on animals, performed by Sir A. Cooper and by myself.* These cases and experiments show, then, that the testicles may be properly developed, though a physical obstacle to the elimination of their secretion is present from birth ; and that so long as the testicles exist entire, though to no purpose, the individual acquires and preserves all the marks of the male sex ; the secretory organ alone appearing to be that upon which the sexual characters depend. The engorgement of the seminal ducts with sperm is liable, it is true, to cause inflammation of the testicle, which may end in atrophy, but this is only a secondary and occasional effect of the interruption in the excretory duct.

Imperfect transition. — It occasionally happens that at birth one or both testicles have not passed into the scrotum, being detained either in the abdomen near the groin, in the inguinal canal, or in the groin, just outside the external ring. In a table of one hundred and three male infants, examined by Wrisberg at the time of birth, it appears that seventy-three had both testicles in the scrotum ; in twenty-one, one or both were in the groin. Of these, five had both, seven the right, and nine the left in the groin; in twelve, four had both, three the right, five the left, only in the abdomen.† According to this table, the imperfection occurs rather more frequently on the left side than on the right, in the proportion of seven to five. In twenty-five cases examined at different ages, varying from five to sixty, — sixteen of which came under my own observation, the remainder being taken from the recorded experience of others, — in thirteen the imperfection was on the right side, and in twelve on the left. Dr. Marshall states, that in the examination of 10,800 recruits, he had found five in whom the right, and six in whom the left testicle was not apparent. In two of these cases there was inguinal hernia on the side where the testicle had not descended.‡ He met with but one instance in which both testicles had not appeared.§ The testicle sometimes remains permanently fixed in the situation in which it is placed at birth || ; but in some instances the passage, though delayed, is completed at some period previous to puberty, and often within a few weeks after birth. Mr. Hunter was of opinion that this completion most frequently

* Diss. sistens Obs. de vesiculæ seminalis sinistræ defectu, integris testibus, vase vero deferente clauso, quoted by Dr. Vrolik, Handboek der Ontleedkundige Ziektekunde, 1st Deel. p. 210.

† Loc. cit. p. 818.

* Vide Sir A. Cooper on Anatomy of the Testis, p. 51., and my Treatise on the Diseases of the Testis, p. 64, and seq.

† Commentatio Soc. Reg. Scient. Goetting. 1778.

‡ Hints to Young Medical Officers in the Army, p. 83.

§ Ibid. p. 207.

|| Persons whose testicles had not made their appearance were called κρυψόρχιδες, or *testicondi*, by the ancients.

happens between the years of two and ten.* Of the twelve cases mentioned by Wrisberg, in which one or both testicles were retained in the abdomen, in one the descent took place the day of birth, in three on the day after, in three others on the third day, in two instances on the fifth day, and in one on the twenty-first day: in the other cases, the testicles had not appeared at the fourth or fifth week after parturition.† My own observations lead me to believe, that if the passage does not take place within a twelvemonth after birth, it is rarely fully and perfectly completed afterwards, without being accompanied with rupture. For the causes which operate at this late period tend as much to promote the formation of hernia as the transition of the testicle. In cases where the testicle makes no appearance before puberty, uneasiness is often experienced at that period, owing to the enlargement of the gland being restrained by the rings and parts composing the inguinal canal. At the same time also, it is often protruded outside the external ring by the movements of the abdomen in respiration.

The causes of a failure in the transition of the testicle have not been much investigated, and as considerable doubt has long prevailed respecting the mode and agency by which this change is effected, no satisfactory explanation could be expected of the circumstances interrupting or preventing it. When we reflect on the nature of that process, as my researches have led me to describe it, it is clear, that there must not only be a perfect adaptation of parts, a due relation between the body displaced and the structures which it traverses, but also corresponding power in the agent by which it is accomplished. There are few muscles in the human body whose development in different individuals varies in a greater degree than that of the cremaster. And if such be the case after birth, it is not unreasonable to presume that similar differences exist in the fœtus before the gland changes its position, and that a failure in the process may be the result of deficient power in the *musculus testis* to accomplish the passage. It is not improbable that this muscle is sometimes paralysed, and that the faulty transition is owing to a want of a due supply of the nervous energy, which we know is often denied to other muscles during fœtal existence, and is the cause of deformities in the feet and other parts, with which infants are often ushered into the world. I think, indeed, we may fairly enumerate paralysis and defective development of the cremaster amongst the presumed causes of the imperfect transition of the testicle. Peritonitis occasionally attacks the fœtus in utero ‡, and produces adhesions between the various abdominal viscera. It is well known that in congenital hernia the testicle is frequently united to a portion of intestine or omentum, and that the formation of these adhesions previous to the transition of the testicle is sometimes the cause of the displacement, the viscera being drawn, together with the gland, into the scrotum. Many facts seem to show that similar adhesions are, on the other hand, an occasional cause of the temporary and permanent retention of the testicle, the cremaster being insufficient to overcome this obstacle to its passage.

In the examination of a man, age sixty, I found the right testicle just external to the abdominal ring; it was small in size, and closely adherent to a portion of omentum. A young man was under my care for many months, on account of an imperfect transition of the testicle on the left side. The gland moved backwards and forwards through the external abdominal ring. By pressure above, it could be forced down sufficiently to admit of being examined. This testicle was much smaller than the right, which was in the scrotum, and I could distinctly make out a portion of intestine closely adherent, which accompanied the organ in all its movements. It is probable that the smallness of the opening in the internal abdominal ring is sometimes a cause of the detention of the testicle, especially in those cases in which the organ is retained within the inguinal canal. Mr. Wilson, an accurate anatomist, was of this opinion*, which is supported by the fact, that the testicle is oftener found in the groin than in the cavity of the abdomen. M. Delasiauve mentions a case, in which, he states, the organ was retained by the border of the outer column of the ring.† Mr. Hunter was inclined to suspect that the fault originates in the testicles themselves. It is difficult to understand how this can be, for as the gland is passive in this process, it can offer no obstacle, unless it grows too large to pass the opening in the abdominal parietes; whereas, it is admitted that the gland when retained is usually below the natural size. Nor does it appear, that the interruption is owing to any want of proper length in the vas deferens, for in a case of imperfect transition in a boy, whose body I examined, I particularly noticed that this duct was so long as to be doubled on itself, and tortuous, a circumstance which has been remarked in other cases by Mr. Mayo‡, Rosenmerhel§, and others. It may be concluded then, that the causes of a failure in the passage of the testicle are various; that this imperfection may result from want of power, or paralysis of the cremaster muscle; from adhesions retaining the gland within the abdomen; and from a contracted state of the opening of the external abdominal ring.

Mr. Hunter states, that when one or both testicles remain through life in the belly, he believes that they are exceedingly imperfect,

* Lib. cit. p. 15.
† Lib. cit. p. 203.
‡ Vide Contributions to Intra-uterine Pathology, by Dr. Simpson, Edinb. Med. and Surg. Journal, nos. cxxxvii. and cxl.

* Lectures on the Urinary and Genital Organs, p. 405.
† Revue Médicale, Mars, 1840, p. 363.
‡ Human Physiology, 3d edit. p. 411.
§ Ueber die Radicalcur des in der Weiche liegenden Testikels.

and probably incapable of performing their natural functions; and that this imperfection prevents the disposition for descent taking place. That they are more defective even than those which are late in passing to the scrotum, he infers from the circumstance, that in quadrupeds, the testicle that has reached the scrotum is considerably larger than the one which remains in the abdomen. Mr. Hunter had seen only one case in the human subject where both testicles continued in the abdomen, but this proved an exception to the above observation, since we are led to conclude that they were perfectly formed, as the person had all the powers and passions of a man.* Professor Owen in commenting upon these observations, states, "It seems remarkable that with this experience Mr. Hunter should have formed from inconclusive analogy, and promulgated, an opinion tending to occasion so much unhappiness as that which attributes exceeding imperfection and probable incapacity of performing their natural functions to testes which in the human subject are retained within the abdomen. That there is nothing in such a situation which necessarily tends to impair their efficiency is evident, from the number of animals in which they constantly form part of the abdominal viscera; and in those in which the testes naturally pass into a scrotum, their continuance in the abdomen, according to our author's own observation, is accompanied only with a difference of size or shape; now we may readily suppose that this may influence the quantity, but not necessarily the quality, of the secretion." There are very few accounts on record of the dissection of undescended testicles. In a case, in which M. Cloquet found the left testicle situated within the abdomen, the gland was well formed, and of the same size as the right, which had descended into the scrotum. The parts taken from an apprentice of Sir A. Cooper, who unfortunately committed suicide in consequence of the infirmity, are preserved in the Museum of Guy's Hospital. I have examined the preparation; and the testicles, which are both within the abdomen, close to the internal ring, appear to be nearly, if not quite, the natural size, and it is stated that the ducts contained semen. In a lad, aged nineteen, whose left testicle was found, by Dr. Bright, within the abdomen, near the brim of the pelvis, the gland was considerably smaller than natural, but the ducts and secreting structure were quite perfect.† These are the only cases of testicles situated within the abdomen in which we have any account of the anatomical condition of the gland. In addition to the evidence they afford of the capability of testicles thus placed to exercise their functions, may be adduced the case of Mr. Hunter, just alluded to, in which a person, both of whose testicles continued in the abdomen, had all the powers and passions of a man; and a case recorded by Mr. Poland, of a man so formed, who was aged twenty-nine. He had all the signs of virility, had married twice, and was the father of two children.* On the other hand, Mr. Wilson mentions the case of a young man, twenty-five years of age, whose testicles never descended. He had some beard, and not an unmanly appearance; but although an imprudent, and in some things a dissipated person, he had never shown the least desire for women, or disposition for sexual intercourse.† John West, a lad, aged sixteen, died in the London Hospital, in a state of universal anasarca. There was no appearance of beard, and only a few hairs were scattered over the pubes. My attention was particularly directed to the state of the genital organs, by observing that the scrotum, which was greatly distended with serous effusion, was not fully developed on the right side. I found the right testicle within the abdomen, about an inch and a half above the internal ring. It was very small, not larger than that of a child two years of age; and on cutting into it, the gland presented the granular appearance usually remarked at that early period.

* Works by Palmer, vol. iv. p. 18.

† Hospital Reports, vol. ii. p. 258.

Passage of the Testicle into the Perineum. — Mr. Hunter first observed that the testicle in changing its situation does not always preserve a proper course towards the scrotum, there being instances of its taking another direction and passing into the perineum. How this is brought about, he remarks, it is difficult to say: it may possibly be occasioned by something unusual in the construction of the scrotum, or more probably, by a peculiarity in that of the perineum itself. For it is not easy to imagine how the testicle could make its way to the parts about the perineum, if these were in a perfectly natural state. He met with two instances of this imperfection. Many years ago a little boy, one of whose testicles had thus deviated from its proper course was brought to the London Hospital. The gland was lodged in the perineum at the root of the scrotum. M. Ricord met with this singular anomaly in two instances. M. Vidal (de Cassis) observed it in two brothers: their father was exempt from it. The testicle abnormally placed was smaller than the other.‡ The irregularity is exceedingly rare, and the above cases are all with which I am acquainted.

Passage of the Testicle through the Crural Ring. — M. Vidal relates the case of a man, one of whose testicles, instead of passing out of the abdomen at the inguinal canal, made its exit at the crural ring. The organ was mounted upon the abdomen like a crural hernia. A portion of intestine traversed the inguinal canal, forming a rupture on that side.§ I know of only one other instance of this

* Guy's Hospital Reports. Second series, vol. i. pp. 162, 163.

† Lectures on the Urinary and Genital Organs, p. 408.

‡ Traité de Pathologie externe, t. v. p. 432. 2eme, edit.

§ Ibid p. 431.

anomaly, which is reported by Eckardt. In this case, the testicle passed out at first through the inguinal canal, but having been returned by the patient into the abdomen, it subsequently escaped at the femoral ring.*

Inversion of the Testicle. — It sometimes happens that the position of the testicle in the scrotum is reversed, so that the free surface presents posteriorly, and the epididymis is attached to the anterior part of the gland, instead of to the posterior. The first case that I met with was that of a man who had a swelling of the right testicle, which puzzled his medical attendant. On examination I found this to be the epididymis thickened from chronic inflammation. I was able clearly to trace the vas deferens proceeding to it along the front of the scrotum. The body of the testicle was unaffected, and its posterior edge was quite smooth and regular. The disposition of the left testicle was normal. On visiting the Hôpital de Midi in Paris, in April, 1849, M. Ricord showed me a case of epididymitis on the left side, in which the gland was thus inverted. He informed me that he had often met with this arrangement. I have since had two patients under my care, one of whose testicles was thus inverted. One was a lad in the London Hospital affected with epididymitis. The other was a gentleman who consulted me for chronic orchitis confined to the body of the testicle. The epididymis being unaffected, the inversion was less perceptible than in the three preceding cases. M. Maissonneuve, in a thesis published in Paris in 1835, I believe first called attention to this irregular disposition, which he states that he had met with many times upon the dead body, and upon the living, and he mentions what I remarked myself in the four cases just noticed, that the inversion was confined to one side. Surgeons should bear in mind the liability to this disposition of the gland in making their diagnosis of the diseases affecting it.

Atrophy of the Testicle. — The testicles, like other organs formed for the exercise of temporary functions, do not arrive at a perfect state of development until a certain period of life, after which their activity ceases, and they become gradually and imperceptibly diminished. Thus we find that in early life they are small in proportion to the size of the body as compared with their condition at puberty, and that as old age advances and the generative functions cease to be called into action, they undergo a diminution in size, their vessels grow less, the seminiferous tubes become small and contracted, and partially obliterated. In the lower animals these changes are far more remarkable than in man, for as the functions of the testicle are exerted only at stated periods of the year, as the rutting or copulating season advances these organs rapidly increase in bulk, and in its decline undergo a proportionate degree of wasting. In man, it sometimes happens that the testicles do not acquire their proper size at the usual period, their development being from some cause or other arrested ; and also, after the organs have arrived at their full and perfect growth, that occasionally one or both suffer a premature decay. Under the head then of Atrophy of the Testicle I shall consider: 1. *Arrest of Development;* and 2. *Wasting.*

Arrest of Development. — If the congenital lesions to which the testicle is liable had not been previously treated of, the cases of absence of the organ already described, might be correctly referred to the present head, as the deficiency in these cases was no doubt the result of an arrest in the early development of the organ. But the cases that I am now about to consider are those in which the subsequent evolution which the testicles undergo at puberty is delayed beyond the usual period, or never takes place at all. Mr. Wilson relates a curious instance of his having been consulted by a gentleman, twenty-six years of age, on the propriety of entering the marriage state, whose penis and testicles very little exceeded in size those of a boy of eight years of age. He had never felt the desire for sexual intercourse until he became acquainted with his intended wife; since that period he had experienced repeated erections, attended with nocturnal emissions. He married, became the father of a family ; and these parts, which at six and twenty years of age were so much smaller than usual, at twenty-eight had increased nearly to the usual size of those of an adult man.* Mr. Wilson mentions this singular case, as it will admit of questions whether the parts alluded to became properly formed as to size, and possessed of the power of secretion, in consequence of being, although so late in life, influenced by the passions excited by attachment to a particular female ; or whether the enlargement and proper action of the parts beginning, occasioned such passion first to exist. He thinks the probability in favour of the former supposition, in which opinion I certainly concur. Lallemand mentions having seen a man about thirty years of age, extremely fat, and without a beard or hair on the pubes, whose penis and testicle appeared to belong to a child of from seven to eight years: he had never experienced erections or venereal desires.† A young man died in the London Hospital of disease of the heart. He was seventeen years and nine months old : the body measured five feet five inches in height, and was plump and well formed. There was no appearance of beard, or whiskers, or of hair on the pubes. The penis and testicles were very small, not larger than they are usually found in boys of three or four years of age. The testicles were about equal in size, and one of them weighed only two scruples and one grain. Both organs were normal in structure, appearing like the glands in early life, when the tubular structure

* Loder's Journal für die Chirurg. ii. Bd. 1 Stff. s. 187.

* Lectures on the Urinary and Genital Organs, p. 424.

† Des Pertes Séminales Involontaires, t. ii. p. 380.

is very indistinctly developed. No spermatozoa could be detected. These were clearly instances of arrest of development of the testicles. As these organs are chiefly excited to action by an operation of the mind, it is easy to understand that they may sometimes remain undeveloped owing to defective organisation of the brain, an absence of sexual desires being invariably remarked in these cases. Cases of wasting of the testicles after injuries of the head, and the frequent absence of the venereal appetite in cretins and idiots, tend to strengthen this opinion. The following are marked examples of defective development of the sexual organs, accompanied with imperfection of the brain. An idiot, aged nineteen, subject to epileptic fits, died of typhus fever in the Hackney union. The youth was of short stature, and the form of the body was not indicative of either sex, but the contour was rounded as in the female. There was no appearance of hair about the face or pubes. The abdomen and other parts were covered with a thick layer of fat. The penis and scrotum were remarkably small, not larger than they are usually found in a child two or three years of age. Both testicles were in the scrotum, but they were of very diminutive size ; the right weighed less than a drachm, and the left not more than twenty three grains. The right gland had descended a very little way below the abdominal ring. The glandular structure and epididymis of both testicles were indistinct, and the vasa deferentia also extremely small. Nothing remarkable was observed in the structure of the brain. Mr. Hovell, the surgeon of the union, also showed me another inmate of the same workhouse, a lad aged nineteen, and of weak mind, whose penis and testicles did not exceed in size those of a boy seven or eight years of age, and who had only a few scattered hairs on the pubes. In the museum at Fort Pitt, Chatham, are preserved two undeveloped testicles about the size of those of a child six months old, but healthy in structure, which were taken from a lunatic 58 years of age. His penis was small and he had never experienced any inclination for sexual intercourse.

Wasting. — In investigating the alterations in the nutritive condition of the testicle, it is very desirable to fix, if possible, some standard by which they may be estimated. The size of the gland is neither uniform nor conveniently appreciated. Its weight, likewise, varies so much in different persons and in the same individual at different periods, according as it has lately exercised its functions or remained inactive, and as it is full of semen or empty, that it is scarcely possible to determine on any accurate standard of this kind. (See p. 976.)

I should consider the testicle of an adult weighing less than three drachms as in a state of atrophy. A testicle in an advaced state of wasting, not arising from disease of the gland, usually preserves its shape, but feels soft, having lost its elasticity and firmness. Its texture is pale and exhibits few blood-vessels, the tubuli and septa dividing the lobes are indistinct, and the former cannot be so readily drawn out into shreds as before. The epididymis does not usually waste so soon nor in the same degree as the body of the testicle. It sometimes however, loses its characteristic appearance, and I have even found it reduced to a few fibrous threads. The fluid pressed out of the wasted testicle and epididymis is entirely destitute of spermatic granules and spermatozoa. In many instances adipose tissue is deposited behind the tunica vaginalis, and encroaches on the epididymis and posterior part of the testicle. Fatty matter is also found in the glandular substance of atrophied testicles, as in one taken from a man aged forty-six, who died of dropy consequent on disease of the kidneys, which was wasted to one fifth its natural size. In addition to the presence of adipose tissue beneath the visceral portion of the tunica vaginalis, I recognised a quantity of yellow matter irregularly disposed amongst the wasted tubuli. This matter on examination in the microscope, proved to be oil globules, and readily dissolved on the application of ether. The structures composing the spermatic cord undergo a corresponding diminution ; the cremaster muscle disappears, the nerves shrink, and the vessels are reduced in size and number. The vas deferens, though small, can generally be injected with mercury as far as the commencement of the epididymis. A testicle, atrophied from disease, is not only of diminished size and weight, but is altered in shape, being uneven and irregular, and sometimes of an elongated form. The surfaces of the tunica vaginalis are adherent and its cavity is partly or entirely obliterated. There is no, or very little, trace of the proper glandular structure, the organ being converted into fibrous tissue of a firm texture. It loses its peculiar sensibility to pressure, but is sometimes the seat of morbid sensibility.

All those causes which produce decay in other parts likewise occasion wasting of the testicle. Thus an impeded circulation, pressure, want of exercise, and loss of nervous influence, have been noticed as causes of atrophy of this gland. To these must be added certain causes which specially affect the testicle. The following case, related by Mr. Wardrop, is a good example of atrophy from defective nutrition. A person, both of whose testicles were completely absorbed, nothing being felt in the scrotum but a loose vaginal coat, died of an aneurism of the aorta, formed at the origin of the spermatic arteries, both of which were obliterated.* A ligature on the spermatic artery is sufficient to cause a total decay of the testicle, which induced the celebrated Harvey † to propose its ap-

* Note to his edition of Baillie's works, vol. ii. p. 315.

† Anatomical Exercitations concerning the Generation of Living Creatures. Lond. 1653, pp. 113, 114.

plication for the removal of a certain form of sarcocele; a suggestion, the credit of which has been improperly assumed in recent years by C. J. Maunoir, of Geneva. The influence of pressure in causing partial atrophy of the testicle, is somtimes remarked in old cases of hydrocele and hœmatocele, in which the gland has been long subjected to compression from the retained fluid.

It has been said that the testicles waste in those persons who strictly adhere to their monastic vows, but I am not aware that there is sufficient authority for this remark. In persons who marry, after many years of abstinence from sexual intercourse, the testicles undergo a certain degree of enlargement. It is a great error to suppose that sexual connection in early life is essential for the preservation of these organs. In cases of enlargement of the prostate the ejaculatory canals sometimes become completely obstructed. Under these circumstances, the semen secreted under excitement having no means of escape, encumbers the testicles for a time, but afterwards becomes absorbed, and it is said that atrophy of these glands sometimes follows; but I have never observed any instance of wasting of the organs from this cause. As examples of atrophy of the testicles from loss of nervous influence, may be adduced cases of paraplegia, in which these organs have been known to waste. Portal mentions the case of a robust man, aged thirty-five, who was attacked with painter's colic, attended with great debility of the lower extremities. The testicles diminished considerably; and although he afterwards recovered from the paralysis of his limbs, these glands always remained wasted; and the man was incapable of the act of generation.* In the xxth volume of the "Medical and Physical Journal," there is an account of a case of recovery after fracture, with partial dislocation of the first and second lumbar vertebræ, followed by paraplegia, in which, three years afterwards, the testicles were found entirely obliterated. It has been stated that the testicles sometimes waste from injuries, or from compression of the spine at the origin of the spermatic nerves. In a man who had received a blow on the lumbar region, the testicles gradually wasted away.†

The most common cause of atrophy of the the testicle is the disturbance in its organisation consequent upon inflammation. As the inflammatory process ceases, the enlarged gland not only becomes reduced to its original size, but it sometimes slowly but steadily diminishes, till at length very little vestige of it remains Mr. Hunter has related three cases in which the testicle decayed in this way.‡ I have met with several instances of atrophy arising from this cause, and there are few surgeons of experience who have not witnessed cases of the kind. Wasting of the testicle has been observed to occur after an attack of orchitis in mumps, arising as it is supposed from the translation of inflammation from the parotid to the testicle. Two cases of cynanche parotidea in the adult, in which atrophy took place in the gland chiefly affected, are related by Dr. R. Hamilton.* I have witnessed one case, in which the patient attributed the loss of the gland to an attack of mumps in his infancy. Wasting is more liable to occur after inflammation of the body of the gland than after consecutive inflammation in which the epididymis is the part chiefly affected. One or both testicles have been found to waste in persons who have indulged too much in sexual intercourse or been addicted to onanism. Baron Larrey met with several cases of atrophy from excessive venery and abuse of strong drinks amongst the soldiers of the Imperial Guard.† Sir B. Brodie has recorded two cases in which wasting was occasioned by over-excitement; in one from onanism, in the other from sexual intercourse.‡ I have also witnessed an instance of total atrophy of the left testicle in a person addicted to excessive masturbation. In this case, and probably in the others just quoted, the wasting was preceded by an attack of inflammation induced by inordinate excitement.

It is a common belief that wasting of the testicle is liable to be induced by the long-continued use of iodine. I have not met with any instance of it, and there are few cases in which the evidence is such as to render it at all clear that the decay of the gland was really occasioned by the remedy. M. Cullerier has published the case of a young man who took from twenty-five to thirty drops of the tincture of iodine for a period of three months for the cure of an obstinate gonorrhæa. This was followed by a state of impotency and partial wasting of the testicles, which lasted a twelvemonth, and the organs never regained their former size and vigour. M. Cullerier mentions another case of temporary loss of virile power occurring from the use of the iodine of iron.§ I feel convinced, however, that if iodine produces wasting of the testicle at all, it does so so rarely, that the liability cannot be regarded as any objection to the free and long-continued use of this valuable remedy. Atrophy of the testicle has been remarked in elephantiasis of the Greeks, a disease in which tubercles are developed in various parts of the skin. Dr. Adams, in an account of the cases of that disease observed in Maderia, states that all those who were attacked with it before the age of puberty never acquired the distinguishing marks of that change in the constitution, and their testicles diminished in size, and that in those affected later in life the testicles became

* Cours d'Anatomie Médicale, t. v. p. 434.

† Baillie's Works, by Wardrop, vol ii. p. 315.

‡ Treatise on the Venereal Disease.

* Philos. Trans. Edinb. vol. ii. art. ix. p. 59.

† Mémoires de Chirurgie Militaires, vol. ii. p. 66.

‡ London Medical and Physical Journal, vol. lvi. p. 297.

§ Mémoires de la Société de Chirurgie de Paris, t. i.

atrophied, and they lost the power of procreation.* Mr. Peacock also noticed a wasting of the testicles in several cases of elephantiasis in the Leper Hospital of Colombo, in Ceylon.† A similar condition of these glands was remarked in a case of this disease, so rare in this country, narrated by Mr. Lawrence ‡, and also in another case at the London Hospital, which I recorded many years ago.§ In a confirmed case however of this disease, in a boy aged thirteen, who was under my care in the year 1849, there was no diminution in the size of these glands. Wasting of the testicles is liable to occur after injuries of the head.

Some years ago I saw a man who had met with an injury of this description, which had been followed by wasting of the testicles, and the development of tumours on each side of the chest, resembling mammæ. He was about fifty-nine years of age, a married man, and the father of several children. He had belonged to the legion in the Queen of Spain's service. About two years and a half previously, in an attempt to jump over a trench, he fell backwards and injured the posterior part of his head. Whilst on the ground he received a bayonet wound on the side, and a sabre cut on the forehead. He recovered from these injuries and returned to England. Since the accident he had completely lost his virility. He had no desire for sexual connection; his penis had dwindled in size; his right testicle had gradually wasted, and was no larger than a horse bean, and the left gland was also a good deal diminished in bulk. The skull at the occiput seemed somewhat flattened. Baron Larrey records the case of a man who was wounded in the back of the neck by a musket ball which grazed the inferior occipital protuberance. He recovered from the injury, but the testicles were reduced to a state of atrophy, and the penis shrunk and remained inactive. He also relates the case of a man of strong constitution and vigorous passions who received a sabre wound which cut off all the convex projecting part of the occipital bone, and exposed the dura mater. The patient lost the senses of sight and hearing on the right side, and his testicles sensibly diminished, and in fifteen days were reduced, especially the left, to the size of a bean.‖ Lallemand had under his care a man thirty years of age, who, in the expedition to Algiers had received a sabre wound at the nape of the neck. His testicles were wasted, and venereal desire as well as erections had entirely ceased.¶ We cannot doubt that in these cases the loss of sexual desire, and the wasting of the testicles were the direct results of the injury to the brain, and they go far to prove the essential dependence of the functions of these glands upon the cerebral organ. The physiologist cannot fail to notice the rapidity with which the atrophy is stated in some of the cases to have succeeded the injury and the extent to which it proceeded. The withering of the testicles, was, indeed, so remarkable, that it can only be attributed to the sudden and complete extinction of the sexual instinct resident in the brain, and (if I may so express myself) to the immediate impression on the system of the future uselessness of these organs. In old age and in lingering diseases the decay of the testicles is extremely slow and gradual, and is never carried to the extent observed in cases of injury to the brain. In fact, men have survived the power or desire of performing the sexual act many years without the testicles being materially reduced in size. We have seen, too, that in the lower animals the testicles have been rendered useless by interrupting the vasa deferentia, without any such striking effect being produced on the glands as occurred in these cases of cerebral injury.

Inflammation of the tunica vaginalis, or acute hydrocele. — The inflammatory changes of the tunica vaginalis resemble those of the other serous membranes. M. Roux injected a hydrocele in a middle-aged man: inflammation was developed, but on the fourth day, gangrenous erysipelas attacked the scrotum, and caused the patient's death on the tenth day after the operation. On examining the tunica vaginalis, he found that it contained a large quantity of whitish serum, in the midst of which floated flakes of albumen; other flakes of the same kind formed a thick coating over the testicle and internal surface of the membranous pouch. The serous membrane beneath appeared slightly thickened, and of a deep red colour. The epididymis and the lower part of the cord were swollen, and constituted the more solid part of the tumour produced by the inflammation. The body of the testicle was not increased in bulk, and it retained its natural consistence.* In the museum of the College of Surgeons, there is a beautifully injected preparation of hydrocele, showing the effects of inflammation after the application of the caustic. It is represented in the annexed wood-cut, which exhibits the sac with part of it cut away to show the swollen state of the epididymis, and the aperture made by the caustic (1); the tunica vaginalis is coated with flocculi of lymph. The sac of an inguinal hernia is seen above the hydrocele. The sound state of the body of the testicle, though surrounded by an inflamed serous tunic, whilst the epididymis partakes in the disease, has been accounted for by Gendrin. He says, when the subserous cellular tissue, which always participates in the inflammation of a serous membrane penetrates into the interior of an organ, it becomes a ready means of communicating

* On Morbid Poisons, p. 265.

† Edinb. Medical and Surgical Journal, vol. liii. p. 139.

‡ Medico-Chirurgical Transactions, vol. vi. p. 214.

§ Vide Medical Gazette, vol. vii. p. 447.

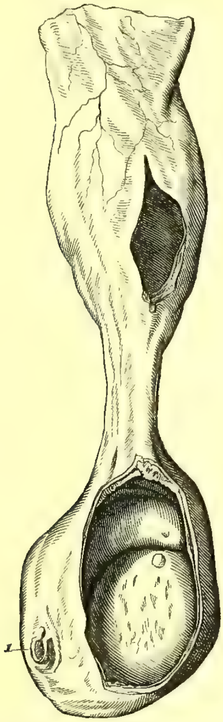
‖ Mémoires de Chirurgie Militaire, p. 262.

¶ Pertes Sémiuales Involontaires, t. ii. p. 41.

* Journal Général de Médicine, &c. t. lviii. p. 25.; quoted from Gendrin, Histoire Anatomique des Inflammations, t. i. p. 143.

the inflammatory action ; but when the contiguous organ or subjacent part is of a dif-

Fig. 638.



ferent structure from that of the cellular tissue, the extension of inflammation inwards is checked. Thus, in the case of the inflamed tunica vaginalis, the cellular tissue readily transmitted the morbid action to the epididymis, but the tunica albuginea arrested its progress to the body of the testicle ; and this explains the fact that after inflammation of the tunica vaginalis, excited by injection, the body of the gland is rarely found to suffer. On the other hand, the epididymis is seldom attacked with inflammation without the disease being quickly propagated to the tunica vaginalis.

The lymph effused in inflammation very often forms adhesions between the opposed serous surfaces, and these after some time are rendered very firm and dense, and in old cases are often converted into a fibro-cartilaginous structure. In a testicle which I examined some little while after an attack of acute inflammation, I found the lymph on both surfaces of the tunica vaginalis presenting a honeycomb or lace-like appearance, similar to that often met with on the pericardium. Inflammation, if violent, may end in the formation of pus ; suppuration is, however, a rare occurrence, unless artificially excited, for the cure of hydrocele. Inflammation of the tunica vaginalis is not only the most frequent disease of the testicle, but it is also one of the most common affections to which the body is liable. In the different disorders of the gland this membrane usually becomes inflamed at some period or other, and adhesions between its opposed surfaces are scarcely less common than those of the pleura. In examining the testicles of twenty-four adults, I found adhesions of greater or less extent in one or both glands in as many as nine instances.

Hydrocele of the tunica vaginalis.—The sac of the tunica vaginalis, like other serous cavities, is liable to dropsical effusion. The fluid effused is usually transparent, and of an amber, pale yellow, citron, or straw colour, and resembles the serum of the blood, but is occasionally thick. According to Dr. Marcet's analysis*, 1000 grains of this fluid of the specific gravity 1024·3 contained 80 grains of solid matter, of which 71·5 consisted of animal, and 8·5 of saline ingredients : hence it appears that this fluid only differs from the serum of the blood in possessing rather less animal matter. In an analysis of the fluid of hydrocele made by Dr. Bostock†, 100·00 parts of the specific gravity 1024 were found to contain

Water - - -	91·25
Albumen - - -	6·85
Uncoagulable matter -	1·1
Salts - - -	·8
	100·00

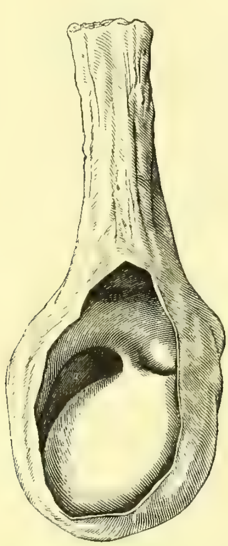
A quantity of flakey matter or flocculent albumen is sometimes found floating in the fluid ; and it frequently contains, especially in old people, cholesterine in the form of a multitude of minute shining particles. The quantity of cholesterine contained in nineteen ounces of dark fluid full of these shining particles, which I removed from an old hydrocele, amounted to nine grains. In the examination of a testicle from a man of colour who died at an advanced age, I found the tunica vaginalis and its investing tissues very thick and firm, and the seat of cartilaginous and osseous deposits ; it contained about three drachms of a thick brownish substance, which was almost entirely composed of cholesterine. This was no doubt a very old case of hydrocele, in which, the more fluid parts having been absorbed, the cholesterine was left behind within the indurated sac. The quantity of serum which is suffered to accumulate varies considerably. In this country it seldom exceeds twenty ounces, though it has been known to amount to several pints. The largest quantity which I have met with is forty-eight ounces. Mr. Cline is said to have removed from Gibbon the historian as much as six quarts.‡

In simple hydrocele the testicle is usually found at the posterior part, and rather below the centre, of the sac : its situation however is subject to variations. Before the occur-

* Medico-Chirurg. Trans. vol. ii. p. 372.
† Ibid. vol. iv. p. 72.
‡ Sir A. Cooper's Lectures, by Tyrrell, vol. ii. p. 92.

rence of hydrocele the tunica vaginalis may have been inflamed and contracted adhesions, so that the testicle may be connected to the membrane in front; in which case the serum accumulates on each side of or above and below the organ. The position of the testicle in front may also be owing to an original inversion of the organ, in which the free surface presenting backwards, the fluid collects in that direction and presses the testicle to the front of the sac. Sometimes there are several adhesions producing a sacculated arrangement and forming what is termed a *multilocular hydrocele*. Occasionally the cysts thus formed have no communication with each other. In two instances I have seen a membranous partition in the sac of a hydrocele, separating it into two distinct cavities, formed by a layer of false membrane. There is one kind of sac or pouch often met with in hydroceles which is not commonly described. It is situated on the inner side of the testicle, but the opening into it is always found on the outer side between the body of the gland and the middle of the epididymis. This sac, which varies very much in size, is formed by the distention of the cul-de-sac which I have described as existing naturally at this part. Two examples of this kind of pouch are contained in the Hunterian Museum. One of them is represented in the accompanying figure. In large hydroceles

Fig. 639.



1, aperture of the pouch between the body of the testicle and middle of the epididymis.

the epididymis is usually elongated and displaced; and instead of a pouch being formed, the central part of the epididymis is drawn to some distance from the body of the testicle. In old hydroceles the sac is often a good deal thickened, the tissues enveloping it being condensed and converted into layers of dense fascia, such as are commonly observed investing only hernial sacs. The fibres, also, of the cremaster muscle, frequently become remarkably developed. This, however, is not constantly the case; for in some instances of hydrocele of large size I have found this muscle atrophied. The thickened sac after many years acquires a cartilaginous character, and it sometimes even becomes ossified. In cases which have been frequently tapped, the sac is often found closely adherent to the skin of the scrotum at the various points perforated by the trocar. In the Hunterian Museum there is a preparation showing a long narrow band of adhesion passing from the anterior part of the testicle across the dilated sac of the tunica vaginalis to the membrane in front, which is supposed to have resulted from a wound of the testicle in the operation of tapping. In all large hydroceles the spermatic vessels are separated and displaced. The glandular structure of the testicle is sound, and the organ capable of exercising its functions. The disease is strictly confined to the investing serous tunic. The testicle is, however, frequently somewhat altered in shape, being flattened by the pressure of the confined fluid; and in some instances has been found partially atrophied.

Hydrocele is generally single, but sometimes occurs on both sides. It is commonly said to form more frequently on the left side than on the right. During the last few years I have registered the new cases of hydrocele coming under my notice in public and private practice. Of one hundred and ten cases of simple hydrocele, one hundred and four were single, and six double. Of the former sixty-two occurred on the right side, and forty-two on the left. This result, which gives a decided predominance to the right side, does not agree with the observations of Velpeau, Gerdy, and Dujat, who found the disease to be more frequent on the left side. Hydrocele in young infants is usually single, and in my experience, more common on the right side. I have seen, however, a few cases of double hydrocele at this early period. When the fluid collected in the tunica vaginalis is attended with enlargement of the testicle, the swelling is termed a *hydro-sarcocele*. This affection is generally consequent on chronic orchitis, but it is occasioned by other morbid changes, malignant as well as innocent. In these cases the disease of the testicle is the original complaint and source of the irritation that excites an undue secretion from the tunica vaginalis.

Congenital hydrocele. — In simple hydrocele, the original communication between the cavities of the peritoneum and of the tunica vaginalis is permanently obliterated; but it sometimes happens that fluid accumulates around the testicle in cases in which the obliteration has not been completed, constituting the variety termed *congenital hydrocele*. The opening of communication between the two cavities is usually small in size, about sufficient to admit a crow's or goose's quill. There is rather a rare variety of congenital hydrocele, in which the testicle is retained in the abdomen or inguinal canal, while the peritoneum, prolonged for a short distance into the scrotum, forms the cyst containing the fluid which is covered only by the integuments and superficial fascia.

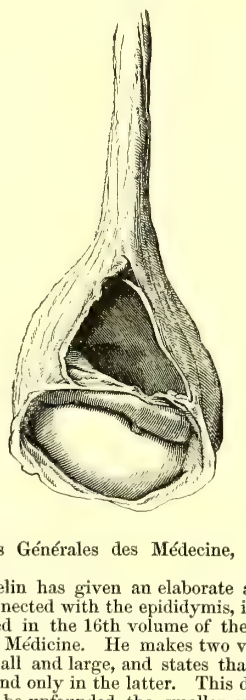
Encysted hydrocele of the testicle. — In this form of hydrocele, fluid is effused into an adventitious cyst or cysts distinct from the sac of the tunica vaginalis. The cyst is composed of a thin delicate serous membrane, and may be developed in three situations: 1. beneath the visceral portion of the tunica vaginalis investing the epididymis; 2. between the testicular portion of the tunica vaginalis and the tunica albuginea, which are thus separated from each other; 3. between the layers of the loose or reflected portion of the tunica vaginalis. The first is by far the most common situation, the two latter being very rare. These cysts are composed of a delicate serous membrane lined with tesselated epithelium, and the fluid contained in them differs from that of simple hydrocele in being perfectly limpid and colourless, and nearly free from albumen. In the cysts formed on the epididymis, the fluid, instead of being limpid, often presents an opaline opacity arising from the presence of spermatozoa.

1. Small cysts not larger than a pea, and even smaller, may frequently be found beneath the serous membrane covering the head of the epididymis, in which they produce a slight depression. In several instances I have seen as many as five and six perfectly distinct cysts connected with this part.

Sometimes one or two small cysts are so embedded in the substance of the epididymis, that they cannot be recognised without dissection. Though these minute cysts generally contain a limpid fluid, I have sometimes found them filled with fluid of a milky hue, and I have even observed matter like pus tinged with blood. These accidental cysts sometimes project the tunica vaginalis before them until they become so far separated from the epididymis, where they were originally developed, as to be attached only by a narrow peduncle formed by a contraction of the connecting tunica vaginalis. Such is the mode of development of those small pendulous pedunculated cysts containing a limpid fluid often found hanging from the head of the epididymis, which were erroneously supposed by Morgagni to be hydatids. I have on many occasions observed them in the different stages of their production. Thus I have seen a pedunculated cyst attached at one part, whilst close to it there was a cyst of a similar nature embedded in the substance of the epididymis. In other instances I have found the cyst very prominent, but still connected by a broad attachment to the tunica vaginalis reflected over it, the membrane not having as yet contracted to form the narrow neck. In all these cases the prolongation of the tunica vaginalis investing the cyst could always be demonstrated by cautious dissection, and between the membrane and the cyst some minute red bloodvessels were generally seen ramifying. These pednuculated cysts never acquire a large size: I have seldom found them to exceed that of a currant. From the exposed situation of the testicle they are liable to be ruptured, the vestiges of them consisting of fimbriated folds of membrane; but this is not a common occurrence. I have seen the delicate peduncle by which the cyst was attached to the epididymis as long as three quarters of an inch. M. Gosselin states that small cysts are sometimes developed in the little appendage to the tunica vaginalis so often found connected with the upper part of the testicle.* This I have never seen.

So common are small cysts connected with the epididymis in the various states and stages I have described, that it is impossible to examine many testicles, especially of persons beyond the age of puberty, without finding them. According to M. Gosselin †, they are liable to be developed from the period of puberty to the age of thirty or thirty-five, but are rare at this period. After the age of forty they are very common, having been met with by him in at least two thirds of the testicles examined. Now when one or more of these cysts, instead of becoming pedunculated, enlarge so as to form a tumour in the scrotum

Fig. 640.



* Archives Générales des Médecine, 4e Série, t. xvi. p. 27.

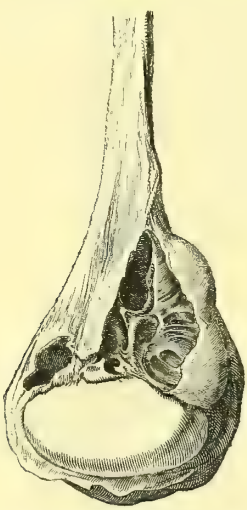
† M. Gosselin has given an elaborate account of the cysts connected with the epididymis, in two papers published in the 16th volume of the Archives Générales de Médicine. He makes two varieties of them, the small and large, and states that spermatozoa are found only in the latter. This distinction I consider to be unfounded, the smaller cysts being simply the early stage of the larger. M. Gosselin assumes the credit of being the first to describe the small cysts. They were, however, minutely described by me, and illustrated in my work on the Diseases of the Testis, published in 1843, of which M. Gosselin could scarcely have been ignorant, since he refers to my account of this form of hydrocele.

they constitute the form of hydrocele, called from its original seat, *encysted hydrocele of the epididymis*. I have observed this description of hydrocele in all its various modifications, from the enlargement simply of a single cyst to the complication occasioned by the varied development of several. As a cyst enlarges the epididymis becomes flattened, and displaced to one side, whilst the testicle is found either in front or at the bottom. It is sometimes at the side, but rarely at the posterior part of the swelling.

In the above woodcut (*fig.* 640.) of a specimen in the London Hospital Museum, the cyst is above the testicle, which is so displaced by it that its anterior edge is directed downwards. The tumour is generally of smaller size than a simple hydrocele, the fluid commonly not exceeding three or four ounces in quantity. I have, however, removed as much as thirty-two ounces from a single cyst. When the hydrocele is composed of several cysts, they are seldom of large size, but form a cluster more or less complicated and irregular, according to their size and number.

A curious sacculated arrangement produced by the development of numerous contiguous cysts may be seen in the annexed figure, (*fig.* 641.) taken from a preparation dissected by

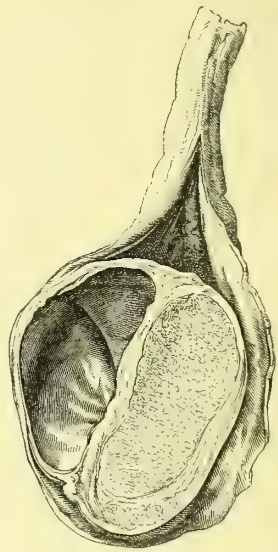
Fig. 641.



myself: part of the walls of the cysts are cut away to exhibit their interiors. The cysts are liable to inflammation, which causes more or less alteration in the quality and appearance of the fluid contained in them. The fluid may become albuminous and assume the straw or amber colour of ordinary hydrocele; and the cyst may contain lymph, form adhesions, or be lined with a false membrane, the fluid being thick and turbid. The cysts sometimes also become filled with blood, constituting a variety of hæmatocele.

2. A cyst may form between the tunica albuginea and the visceral layer of the tunica vaginalis, separating the two membranes which are naturally closely adherent to each other. This is a very rare form of hydrocele. A specimen which I discovered accidentally in dissection, is represented in the annexed woodcut. (*fig.* 642.) The cyst contained about two

Fig. 642.



drachms of fluid, and is situated along the front of the testicle; it is a little thickened. A section of it is preserved in the Hunterian Museum. Sir B. Brodie has described a very similar specimen.* In the museum of St. Thomas's Hospital there is a specimen of a small cyst apparently developed from the epididymis: in its subsequent growth it had extended on the fore-part of the testicle, separating the tunica vaginalis from the tunica albuginea.

3. In examining a healthy testicle I once found six or seven small cysts about the size of currants, studding the surface of the loose portion of the tunica vaginalis. Two of them were situated in a part of the membrane extending up the cord. They projected internally, and contained a limpid fluid. I have twice since seen a similar kind of cyst in the same portion of the tunica vaginalis. Similar adventitious cysts have also been observed on the internal surface of the sac of a simple hydrocele, and a preparation of the kind is contained in the Hunterian Museum. If a cyst developed in this membrane were to increase to any size, it would constitute a swelling which might be appropriately termed *an encysted hydrocole of the tunica vaginalis*.

A circumstance of much interest in connection with encysted hydrocele of the testicle, is the occurrence of spermotozoa in the fluid contents of the cyst, a discovery made by the late Mr. Liston in 1843. During the last six years I have met with them in as many as twenty cases of encysted hydrocele: indeed, in the majority of instances in which

* Lond. Med. and Phys. Journal, vol. lvi. p. 522.

I have searched for them. They were found in subjects of various ages from 30 to 75, and in cysts of all sizes from that of a filbert to the largest which the hydrocele attains. The fluid in some instances contained these bodies in remarkable abundance; in others they existed sparingly. When very numerous, they give to the fluid an opaline opacity, or an appearance resembling cocoa-nut milk which is so characteristic as to enable the surgeon to predicate their presence from the appearance of the fluid alone without minute examination. If the fluid be allowed to remain at rest in a glass vessel, the spermatozoa subside to the bottom, rendering the lower portion more opaque than the upper. The fluid also exhibits slight traces of albumen, when tested in the usual way, which is not the case with the ordinary pellucid colourless fluid of encysted hydrocele. The spermatozoa were often as lively as in fresh semen. They were observed more frequently in the larger cysts than in the smaller. I once found them in fluids removed from two distinct cysts connected with the epididymis of a man about sixty years of age. I have detected them in the fluid from encysted hydroceles tapped for the first time, and also in the examination of small cysts connected with testicles removed after death. I removed from an old man aged 75, who had had encysted hydrocele for eight years, and which had never been tapped before, as much as thirty-two ounces of fluid, which contained an abundance of spermatozoa. They were also detected in fluid taken from a man aged 54, who stated that the tumour had existed for eight years, and had never been operated on.

Various opinions have been broached to account for the existence of spermatozoa in the encysted form of hydrocele of the testicle. The explanation which seems to me the most reasonable and probable, is that which I offered shortly after the occurrence of spermatozoa in encysted hydroceles was first discovered*, viz. that their presence is probably owing to the accidental rupture of a seminal canal, and the escape of its contents into the cyst of an existing hydrocele. The close proximity of the efferent tubes, the slight texture of the ducts and delicate walls of the cyst, and the liability of the part to contusion and injury, when a swelling even of moderate size exists, seemed to me to favour this view. The circumstance that spermatozoa are never found in very small cysts show that they are not originally formed there, but are a subsequent addition to their contents. Since my attention has been drawn to this subject I have investigated the history of the cases of encysted hydrocele containing spermatozoa, which came under my notice. In nearly all instances the patients assured me that the swelling had gradually formed after an injury to the testicle; and in two cases it was clear that a small cystic swelling had long existed in a stationary state, but after a slight blow had begun to enlarge. I strongly suspect that, in these cases, a duct had been ruptured by the contusion, and that the irritation consequent on the injury, and perhaps on the addition of such lively bodies as spermatozoa to the fluid contents of the cyst, had led to its further development. I have, it is true, failed in establishing the fact of a communication between the duct and the cyst by anatomical examination. In two instances of large encysted hydrocele containing spermatozoa, which I had an opportunity of examining, I injected the vas deferens with coloured size, but the duct was so clogged with semen that the fluid could not be made to reach the head of the epididymis, to which the cyst was attached. In a preparation of large encysted bilocular hydrocele containing spermatozoa, shown me by Mr. Busk, the vas deferens had been injected with mercury, but none of the metal reached the upper part of the epididymis. The cyst evidently arose from the head of the epididymis, and was embedded a little in its substance. In these cases no opening communicating with a duct could be discovered on examination of the cysts, but this is not surprising, since the communication must be extremely minute, so as readily to escape detection, or it may even have been obliterated.

Spermatozoa are stated to have been found in some two or three instances in fluid removed from the tunica vaginalis. It is not improbable that these cases may have been encysted hydrocles mistaken for simple. The diagnosis is sometimes very difficult, and in the case of the cyst examined by Mr. Paget,* this error was made before death by a hospital surgeon. I have, however, found spermatozoa in the sac of the tunica vaginalis, and the following case will account for their presence. A man aged fifty-four died in the London Hospital of disease of the kidneys, of one of the ureters, and of the bladder, which appeared to be consequent on a severe blow on the loins about six weeks before. The tunica vaginalis of one of the testicles contained two ounces and a half of slightly opaque fluid, in which a few spermatozoa were found. There were three small cysts containing fluid immediately connected with the epididymis, and also at one spot an irregular ragged membranous appearance, evidently caused by the rupture of a cyst. It is most probable that the spermatozoa had escaped from this cyst, which may indeed have been burst at the time of the injury. I have examined the fluid from the tunica vaginalis in a large number of instances without finding these bodies, and I believe their occurrence in the common form of hydrocele to be extremely rare.

Diffused Hydrocele of the Spermatic Cord.— Mr. Pott has given an admirable account of this affection, under the denomination of *hydrocele of the cells of the tunica communis.*† It has likewise been particularly described by

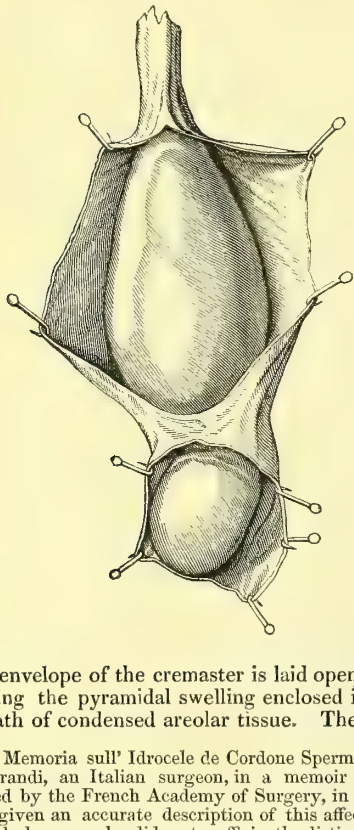
* Practical Treatise on Diseases of the Testis. Appendix, p. 541.

* Medico-chirurgical Trans., vol. 27. p. 398.

† Vide his Treatise on Hydrocele.

Scarpa.* The disease is of the nature of simple œdema, a watery fluid being diffused throughout the areolar tissue connecting the vessels of the spermatic cord, and enclosed in a sheath, which is invested by the musculo-aponeurotic structure of the cremaster muscle. When the complaint has lasted some time, the sheath is found more or less thickened. The areolar tissue within is infiltrated with a limpid albuminous serum of a white or yellowish colour, which flows out in the course of the dissection. The cells infiltrated with serum are converted into large vesicles, some of which are big enough to admit the tip of the finger. These cells are larger and more delicate towards the base of the swelling, where they sometimes disappear altogether; so that there is only one considerable cavity at the lowest and more depending part. The base of the swelling corresponds to the point at which the spermatic vessels join the testicle, and at this part a dense septum cuts off all communication with the tunica vaginalis. In some instances the effusion extends along the cord into the abdomen, as in a remarkable case related by Mr. Pott. In the annexed figure of this affection, (*fig.* 643.), taken from Scarpa,

Fig. 643.



the envelope of the cremaster is laid open, exposing the pyramidal swelling enclosed in its sheath of condensed areolar tissue. The testicle and tunica vaginalis are seen below it. In general anasarca the areolar tissue of the spermatic cord, as well as of the scrotum, is frequently distended with serum; but œdema of the cord alone is a very rare affection. Sir A. Cooper makes no allusion to it, and Mr. Pott, to whom we are indebted for so good and accurate a description of this species of hydrocele, probably met with a greater number of cases of it than have occurred in the practice of any surgeon since his day.

Encysted Hydrocele of the Spermatic Cord.— A cyst containing fluid may be developed in the loose areolar tissue of the spermatic cord. The cyst is formed of a thin transparent membrane, possessing the ordinary characters of a serous membrane, and contains generally a limpid aqueous liquid, having little or no albumen, but sometimes a straw-coloured serum similar to the fluid of simple hydrocele. It is of an oval form, and its size, though variable, seldom exceeds that of a hen's egg, and is usually smaller. It is loosely attached by areolar tissue to the vessels of the cord which are situated at its back part, but become separated and displaced by it. The cyst is invested by the common integuments, superficial fascia, musculo-aponeurotic sheath of the cremaster muscle, and fascia transversalis. It may occur either immediately above the testicle, in the middle of the cord, or just below the abdominal ring, and even within the inguinal canal. Usually there is a single cyst, but occasionally several are developed, and a chain of them has been formed along the cord. The cyst and its contents are liable to changes consequent upon inflammation. Encysted hydrocele of the cord appears to originate, in general, in a partial or imperfect obliteration of the prolongation of peritoneum drawn down at the period of the transition of the testicle. I have already described the different appearances presented by the remains of this prolongation, which, it has been remarked, sometimes consists of a single cyst, or of two or more sacculi, moistened by a serous fluid. When this fluid accumulates in any quantity, an encysted hydrocele is the result. Such is obviously the mode of origin of this affection when occurring in infants, and no doubt in adults it generally originates in the same way. M. J. Cloquet has remarked that the remains of the peritoneal process accompanying the testicles in their descent were met with in male subjects of all ages, and he mentions as a singular circumstance, that they were nearly as frequently found in the old as in the young subjects.* My own dissections agree with the observations of this accurate anatomist. In the museum at the London Hospital there is a preparation showing the tunica vaginalis continued for about two inches up the cord, and, immediately above it, an encysted hydrocele, which was taken from an adult subject. In dissecting the body of a man, aged eighteen, I found an encysted hydrocele of the cord

* Memoria sull' Idrocele de Cordone Spermatico. Bertrandi, an Italian surgeon, in a memoir published by the French Academy of Surgery, in 1778, has given an accurate description of this affection, which, however, he did not sufficiently distinguish from the encysted hydrocele of the cord. He dissected on the dead body a diffused hydrocele, which contained twenty ounces of fluid.

* Description of the parts concerned in Inguinal and Femoral Hernia, tr. by McWhinnie, p. 25.

above the testicle in close contact with the tunica vaginalis. Immediately above this cyst, but quite distinct from it, there was a narrow and empty serous sac three inches in length, with a contracted neck, and communicating with the abdomen. They are figured in the accompanying engraving, with the hernial sac

Fig. 644.

laid open, and part of the parietes of the encysted hydrocele cut away to expose their interiors. The position of the testicle is so changed that its anterior border is directed downwards. In the examination of the body of a man who died of disease of the heart, I found on the right side a thickened and empty serous pouch, extending for about an inch and a half below the external abdominal ring. Directly below it was an independent cyst, capable of containing a walnut, similar in structure to the hernial sac, but lined by a thin false membrane. The tunica vaginalis, which was healthy in structure, extended up the cord as far as the cyst, from which it was separated by a thick and firm partition. In opening the body of a sailor who died with ascites, I noticed at the internal ring a small, delicate, transparent, pedunculated cyst, not larger than a nut, projecting into the cavity of the abdomen. In the spermatic cord, there was a large serous cyst, which extended into the inguinal canal, and contained a small quantity of transparent fluid. A small orifice at its upper part opened into the pedunculated cyst, which proved to be a process from the cyst in the cord. In fig. 644., I have given a representation of an inguinal hernia, combined with an elongated encysted hydrocele of the cord; and in fig. 647., a representation of an encysted hæmatocele of the cord, in which the tunica vaginalis remained unobliterated as far up as the cyst, whilst a hernial sac is situated immediately above it. These dissections confirm the view taken by Sir A. Cooper, and now commonly adopted, of the mode of origin of encysted hydrocele of the spermatic cord in the adult.

Complications of hydrocele.—The following are the principal: 1. Simple hydrocele, combined with encysted hydrocele of the testicle. 2. Simple hydrocele, combined with encysted hydrocele of the spermatic cord. 3. Simple hydrocele, combined with diffused hydrocele of the spermatic cord. 4. Oscheo-hydrocele, including both simple hydrocele and encysted hydrocele, combined respectively with inguinal hernia.

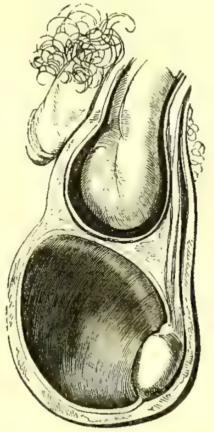
1. The first is not an uncommon complication. In the dissection of these parts, I have often found the tunica vaginalis distended with three or four drachms, and even an ounce or two of serum, two or more small distinct cysts being at the same time connected with the upper part of the epididymis; and I have twice met with this complication in both sides in the same individual. The small adventitious cysts appear to be the original disease, the irritation produced by them being in all probability the cause of the increased quantity of fluid in the tunica vaginalis.

2. The second complication is somewhat rare. In the pathological collection at the London Hospital, there are two specimens of a collection of fluid in the tunica vaginalis associated with an encysted hydrocele of the spermatic cord. In one of them the tunica vaginalis is unobliterated for about two inches along the spermatic cord, and the encysted hydrocele is immediately above it. In the other preparation it is apparent that both sacs have been the seat of inflammation, false membranes being contained within them. This complication sometimes occurs in infants.

3. Simple hydrocele associated with diffused hydrocele of the cord is also rare. A good delineation of this complication is given in Scarpa's work.

4. Scrotal hernia may be combined with hydrocele. A voluminous hydrocele, if un-

Fig. 645.



supported, appears to be highly favourable to the occurrence of hernia and the extension of the sac, by dragging down the peritoneum. Oscheo-hydrocele is not an uncommon complication. In most of the cases which I have met with, the hydrocele was placed below and free of the rupture, and in a few only in front of it. I have never found the hernial sac covering the fore part of a hydrocele. The ordinary relations of hydrocele and scrotal hernia may be seen in the accompanying woodcut. In figure 638., the sac of an inguinal hernia is represented at some little distance above a small hydrocele. Dupuytren states that, when a hydrocele is placed in front of a hernia, a part of the omentum or intestine sometimes descends into a cyst, which projects into the hydrocele, and is formed of the hernial sac and serous fold of the tunic of the testicle.* This complication is of the nature of the *hernia infantilis*, described by Mr. Key, and called by Sir A. Cooper *encysted hernia of the tunica vaginalis*.

Hæmatocele.— This is a term applied to the swelling occasioned by effusion of blood in the sac of the tunica vaginalis, or in a cyst connected with the testicle; it is also applied to tumours produced by extravasation, either in the substance of the spermatic cord, or in the sac of an encysted hydrocele of this part. *Hæmatocele of the testicle*, in which blood is effused into the tunica vaginalis, is by far the most common form of this affection. The extravasation may take place in a healthy state of the parts, or it may succeed, or be combined with hydrocele. The first variety occurs from the accidental rupture of some blood-vessel, probably one of the vessels ramifying between the tunica albuginea and tunica vaginalis testis, owing either to a blow or a violent straining effort. The second variety, in which the extravasation takes place in combination with hydrocele, is of more frequent occurrence than the first. It may also be produced by a blow, or by the wound of some vessel, in the operation of tapping. A blow occasions a slight rupture of the tunica vaginalis, and of some of the enlarged vessels ramifying outside it, and the blood which escapes passes into the sac and mixes with the fluid of the hydrocele, producing a sudden increase in the size of the tumour. The liability to this accidental effusion of blood is increased by a diseased condition of the arteries, such as is commonly met with in old people. The quantity of blood effused under these circumstances varies considerably. It may be merely sufficient to impart a red tinge to the serum. In general, however, it is greater in amount, and coagula are formed, which remain undissolved in the fluid. A hæmatocele may be produced in the operation of tapping a hydrocele, in two ways. It may be occasioned by the accidental wound of some vessel ramifying over the tunica vaginals, which, instead of bleeding externally, or into the areolar tissue of the scrotum, pours its blood into the sac of the hydrocele ; or it may be caused by the trocar or lancet penetrating too far, and wounding the testicle or spermatic artery.

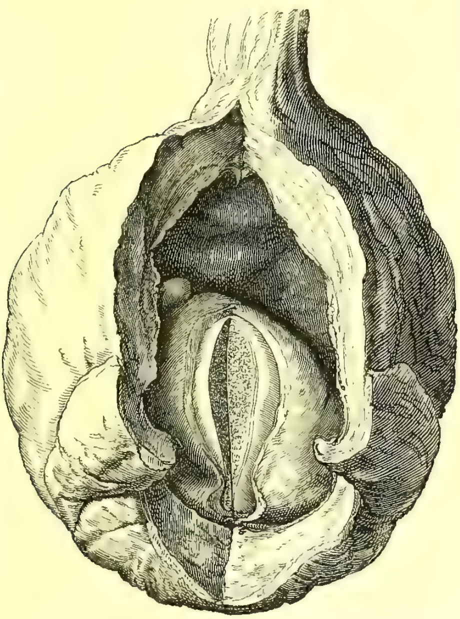
In hæmatoceles which have existed for a long period, the blood becomes changed into a substance resembling coffee grounds, of a brownish-red, or chocolate colour, and more or less fluid. The coagula sometimes present a cellular or honeycomb appearance, the cells being filled with a reddish serum. Occasionally the blood is found converted into a solid fibrinous substance, of a yellow or fawn colour, arranged in firm layers, similar to the coagula lining the sac of an aneurism. In many instances the effused blood is felt as a foreign body, and produces inflammation in the tunica vaginalis, which becomes coated with lymph, and this mixing with blood and serum modifies the appearance of the contents of the cyst, rendering it turbid and of a lighter colour. Sometimes the inflammation goes on to suppuration, in which case pus is also found in the sac. The inflammation usually extends from the tunica vaginalis to the areolar tissue and fascia external to the sac, which in recent cases are found infiltrated with serum and lymph, and in cases of old standing become greatly thickened, indurated, and compacted. In a case of hæmatocele, occasioned by the wound of a vessel in tapping a hydrocele in which I was consulted, the inflammation which ensued caused, in the course of a fortnight, great thickening of the tissues external to the sac, and the formation of an abscess in the scrotum on one side of the hæmatocele. I have found the tunica vaginalis and tissues investing it as much as half an inch in thickness, and very firm and dense.

These changes in the sac are produced by a more chronic form of inflammation of the fascia and areolar tissue investing the sac. In these old cases, the internal surface of the tunica vaginalis instead of presenting its natural smooth and polished surface, is rough, granular, and irregular, and feels as dense and tough as a piece of leather, having lost all the characters of a serous membrane. In hæmatocele, the testicle preserves the same relation to the remainder of the tumour as in simple hydrocele, being situated at the posterior part, and rather below the centre. Its position, however, is liable to similar alterations as occur in hydrocele, and they are dependent upon the same causes. A young man had a hydrocele, which had succeeded to an attack of secondary orchitis, occasioning an adhesion of the gland to the front of the sac at its lower part. The case became converted into a hæmatocele by the wound of a vessel in the operation of tapping. Inflammation ensued, and it became necessary to lay open the sac. The surgeon, in carrying the incision to the lower part of the tunica vaginalis, divided the vas deferens and severed the sound testicle nearly in two with his bistoury, the thickening around the sac having prevented him from detecting the gland in its unusual situation. In hæmatocele, the

* Leçons Orales. Brussels edit. t. iv. p. 233.

glandular structure of the testicle sometimes disappears in the same manner as in old cases of hydrocele, atrophy being occasioned by the long continued pressure arising from the extravasated blood. Sir B. Brodie has recorded two cases of old hæmatocele, in which the testicle was completely atrophied.* In the examination of a large hæmatocele which had existed for many years, and was removed by operation, under the impression that it was a solid enlargement of the testicle, I found the tunica vaginalis nearly half an inch thick, and full of a soft friable substance of a chocolate colour; the testicle, which was situated at the posterior part of the cavity, was somewhat flattened, and partly imbedded in the thickened cyst; but the glandular structure was perfectly healthy, and the bulk of the organ scarcely less than natural. The hæmatocele, with the sac and testicle laid open, is represented in the accompanying figure. The

Fig. 646.



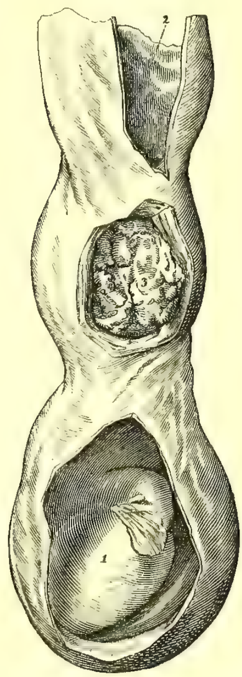
structure of the testicle is usually indeed sound in hæmatocele, but its nutrition becomes impaired when the disease is of very old standing.

Encysted hæmatocele of the testicle, or effusion of blood in a cyst connected with the testicle, is an extremely rare affection. The following is the only case of the kind that I have met with. I was requested by one of my colleagues at the London Hospital to examine a case of painful tumour connected with the left testicle. The patient, aged eighteen, had injured the part three months before. The scrotum was much swollen at the time of the accident, and the tumour formed afterwards. It was about the size of a chesnut, quite moveable, but attached to the epididymis. The cyst was opened with a lancet, and exit given to a quantity of dark coagula lodged in a thickened cyst, the interior of which was lined by a rough false membrane. No doubt the cyst existed before the injury, which caused effusion of blood and inflammation, and thickening of the cyst.

Hæmatocele of the spermatic cord is an affection which was first noticed by Mr. Pott. It is generally produced by the accidental rupture of a spermatic vein, during violent and sudden exertion, as in straining to lift a heavy weight, when blood immediately escapes into, and infiltrates the loose areolar tissue along the cord, where it accumulates, its further diffusion being prevented by the fascious envelope of this part. Mr. Pott has related three cases, all of which happened in this way. I have met with this variety of hæmatocele, coupled with extravasation in the scrotum, in two or three instances of contusion, of this part. In one case in which the effusion in the cord was on the left side the spermatic veins were varicose.

Encysted hæmatocele of the spermatic cord results from the effusion of blood into the cyst of a hydrocele of this part. But it is an affection only known to me from preparations. In the Museum of St. Bartholomew's Hospital there is a specimen of the kind. The cyst is empty: but it is described to have contained blood, and its walls are deeply stained with the colour of partially decomposed blood. Its lining membrane is wrinkled and coarsely granular, and the tissues around

Fig. 647.



1, testicle; 2, hernial sac; 3, encysted hæmatocele.

* Lond. Med. and Phys. Journal, vol. lviii. p. 299.

it are thickened, brawny, and adherent together. In the Hunterian Museum there is a specimen (No. 2460.) of old encysted hæmatocele of the spermatic cord. A good-sized cyst, lined by a membrane, polished and a little wrinkled, is filled with a soft, tawny-looking granular matter, resembling the altered coagulum of blood observed in ordinary hæmatocele after long maceration in spirit. The tissues around the cyst are thickened and indurated, just like those around an old hæmatocele of the testicle. There is a hernial sac immediately above it, and a hydrocele below, with the sac open for some distance up the cord as far as the cyst of the hæmatocele. The latter does not communicate either with the tunica vaginalis, or the hernial sac. In the Musée Dupuytren at Paris, I also saw a preparation of this affection, which occurred in the practice of the late M. Blandin.

Orchitis. — Inflammation of the testicle occurs in two forms, acute and chronic ; and it may commence either in the body or secreting part of the organ, or in the epididymis. Inflammation beginning in the body of the testicle may be idiopathic, or may be excited by external violence: the disease is at first confined to the interior of the organ, the epididymis and tunica vaginalis being affected only secondarily, and sometimes entirely escaping. Orchitis is far more frequently a consecutive affection than a primary, the inflammation being transmitted from the urethra along the vas deferens. In this latter form of orchitis, which is familiarly known by the term *hernia humoralis*, the epididymis is first attacked, and the tunica vaginalis generally participates in the disease.

Acute Orchitis. — Few pathologists have examined a testicle in a state of acute inflammation, and I am unacquainted with any authentic account of the alterations in structure from inflammation originating in the body of the gland. I have twice had the opportunity of examining a testicle affected with acute secondary orchitis ; and the following description of the pathological appearances is drawn up from these investigations, and from the account of the dissection of two testicles affected with gonorrhœal inflammation recorded by M. Gaussail.* The tunica vaginalis is more or less distended with lymph or albuminous matter, infiltrated with reddish serum, which form loose adhesions between the opposed surfaces of the membrane ; these adhesions are so slight as easily to admit of being broken down with the finger. The membrane is injected with a multitude of minute red vessels which ramify in various directions and form a compact network. At a later period red vessels may be traced proceeding from the free surface of the tunica vaginalis to the false membranes forming the adhesions. The volume of the testicle appears very little if at all increased, the great bulk of the tumour being occasioned by the swollen epididymis and effusion into the serous sac. When cut into, the gland appears somewhat darker than natural, from a congested state of its vessels. The epididymis, particularly the lower part, is enlarged to twice and sometimes thrice its natural size, and feels thick, firm, and indurated. This enlargement is produced by the effusion of a brownish deposit in the areolar tissue between the convolutions of the duct. The coats of the vas deferens are thickened, and the vessels ramifying near them injected, sometimes along the whole extent of the duct. Albuminous deposit is found in the areolar tissue around the tortuous part of the vas deferens and tail of the epididymis, which frequently forms the bulk of the swelling observed in these cases. Owing to the epididymis being the part chiefly and most constantly affected in consecutive orchitis, some of the modern French writers have denominated the disease *epididymitis*.

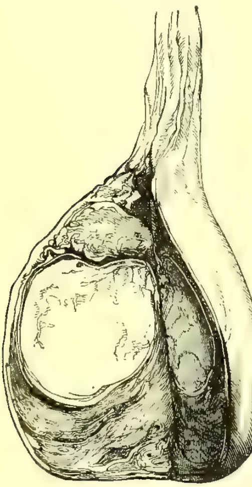
In treating of the acute inflammatory changes in the tunica vaginalis, I particularly remarked that the inflammatory action was very liable to extend to the substance of the epididymis, but not to the body of the testicle, and I noticed the pathological law enunciated by Gendrin, by which the circumstance was accounted for. We find, too, that inflammation of the epididymis is much more readily propagated to the tunica vaginalis than inflammation originating in the glandular structure of the testicle. When inflammation commences in the body of the gland, the enlargement takes place slowly, and is seldom considerable until the disease has existed for some length of time, which is easily explained by the unyielding texture of the tunica albuginea, and the circumstance of the tunica vaginalis remaining unaffected. Suppuration occasionally takes place in this form of orchitis, whereas in consecutive inflammation the formation of pus in the substance of the gland is of rather rare occurrence. I do not mean, however, to assert, that the glandular structure of the testicle never suffers in consecutive orchitis, for I believe that it does so in some instances ; but, according to my observations, and I have paid some attention to the subject, it very commonly escapes, the inflammation not extending further than to the epididymis. When inflammation terminates in suppuration, the matter is so slow in making its way externally, owing to the density, thickness, and low organisation of the tunica albuginea, that it generally burrows in various directions, producing numerous sinuses throughout the gland, and disorganising its delicate structure. The matter sometimes becomes encysted, forming a separate abscess.

In these cases, when the matter effused is small in quantity, after all inflammation has subsided, the more fluid particles are absorbed, and the pus remains for a considerable time in the form of an indolent concrete mass, which has been mistaken, after death, for tubercular deposit. The pus when found in this concrete state appears at first sight very

* Mémoire sur l'Orchite Blennorrhagique, Archives Générales de Médecine, tom. xxvii. p. 210.

like crude tubercular deposit; but on further examination it will be found to be contained in a distinct cyst, from which it may easily be separated, and the structure of the testicle will be perceived to be more or less altered from its healthy state; whereas in tubercular disease, the morbid deposit is in immediate contact with the tubular structure, which, though atrophied by pressure, is usually in other respects sound. Concrete pus may likewise be mistaken for the firm yellow matter effused in chronic inflammation. It differs from it, however, in being friable and easily broken up, and also in being enclosed in a cyst, whereas the yellow fibrinous substance is homogeneous and consistent, and almost inseparably diffused amongst and connected with the convoluted tubuli around it. The distinctive characters just described will be easily recognised on comparing the accompanying representation of concrete pus encysted in the testicle with *fig*. 651.

Fig. 648.

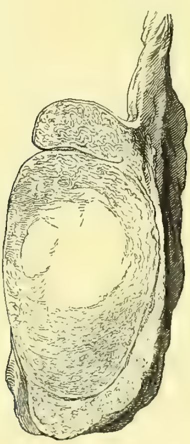


I examined two enlarged testicles taken from a man who died suddenly. Both glands had formerly been attacked with acute inflammation, and for some months before death they had been the seat of chronic pain. In the left testicle, which was the larger of the two, from two to three drachms of thick yellow inspissated pus were contained in a distinct cyst, which occupied the centre of the gland. There was no trace of tubuli, but the remainder of the organ was composed of a fibrous tissue: the sac of the tunica vaginalis was obliterated by close adhesions. The tunica vaginalis of the right testicle contained about half an ounce of yellowish serum and in the centre of the gland there was a small concrete abscess, but the tubular structure was apparent and very little diseased. Pus existing in this concrete or inspissated state often keeps up pain and irritation for a long period, and renders the testicle liable to repeated relapses of inflammation.

Suppuration occasionally takes place in the epididymis. In several cases of consecutive orchitis which have come under my care, at a late period of the disease an abscess formed in the areolar tissue around the termination of the epididymis and inflected portion of the vas deferens, and burst at the most depending part of the scrotum. In many instances, after acute orchitis has subsided, the testicle is restored to its natural condition; in other cases, permanent changes of a serious nature are the consequence. I have observed in testicles that have been affected with inflammation some time before, that the septa appear to be more distinct, and to enter more largely into the composition of the gland than is natural; that the small seminal tubes are less numerous and apparent; and that a great part of the organ is converted into a dense white fibrous tissue, without the presence of tubuli. In these cases the fibrinous matter effused in the areolar tissue connecting the tubuli, not having been absorbed after the cessation of inflammatory action, had occasioned partial atrophy of the proper structure of the organ, and been converted into the dense tissue just described. Complete atrophy is one of the most serious results of acute inflammation of the testicle. I have already remarked that the disturbance in the organisation of the testicle consequent upon inflammation is the most common cause of wasting. Consecutive orchitis, if not checked in the early stage, seldom subsides without leaving behind distinct traces of its existence, which never disappear entirely during the remainder of the patient's life. The epididymis frequently remains enlarged, presenting an indurated irregular knotty swelling, seated usually at its lower part, which is occasioned by the presence of a dense hard deposit between the convolutions of the duct and around the inflected portion of the vas deferens. On making a section of the epididymis in this state, I have often observed not only a highly thickened condition of its duct, but also, in some instances, very considerable dilatation; so that the point of a fine probe might be introduced into the canal without difficulty, its area being increased four or five times. These effusions about the duct rarely if ever produce its obliteration, the yielding nature of the tissues preventing this injurious result. In old cases the epididymis acquires the density and consistence of cartilage, and sometimes even of bone. These changes are rarely found without the presence of old adhesions, obliterating partially or completely the sac of the tunica vaginalis. The coats of the vas deferens are also found for some extent thickened and indurated. The alterations noticed in the body of the testicle have been observed, in some instances, coexisting with those in the epididymis; but in by far the majority of cases, the glandular structure is unimpaired. In only two cases in which the epididymis was thus diseased, have I remarked a decidedly atrophied condition of the organ. The absence of pressure, owing to the unresisting nature of the membrane investing the epididymis, appears to prevent the obliteration of the duct of which it is composed, and thus accounts for atrophy occurring much more rarely after consecutive orchitis than after inflammation originating in the body of the gland, where the delicate seminal tubes are enclosed in the firm unyielding tunica albuginea.

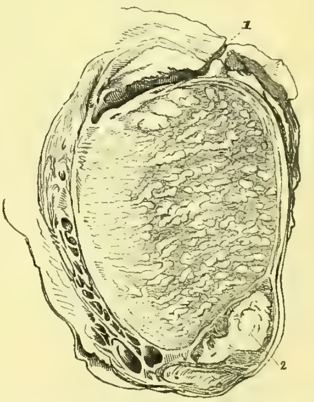
Chronic orchitis. — The testicle is liable to a form of inflammatory swelling of a distinct and chronic character, which occasionally succeeds acute orchitis but far more commonly arises spontaneously. The disease is of importance; for, if unchecked, it tends to disorganise and destroy the gland. The chief anatomical character of this form of inflammation is the deposit of a peculiar yellow, homogeneous, inorganic matter in the structure of the testicle. This substance when first formed is of soft consistence, but afterwards becomes firm and solid, and so closely adherent and intimately blended with the proper structure of the organ as not to admit of separation without much difficulty. In some instances there is a single deposit of this substance in the centre of the glandular structure, as in the preparation from which the annexed woodcut was taken. In others

Fig. 649.



several are interspersed throughout the testicle, portions of sound gland intervening. In a case of chronic enlargement of both testicles taken from a patient who died of *ramollissement* of the medulla spinalis, I found six or seven separate deposits of this yellow matter in the substance of the right testicle, and a single one only in the body of the left. The small masses as they enlarge coalesce, or the single one increases, until the whole testicle presents an uniform yellowish-white appearance. The epididymis is frequently invaded at the same time by a similar kind of morbid deposit, which also tends to obliterate its tubular structure. This, however, is not, as some pathologists suppose, a constant occurrence; for in the majority of testicles thus diseased that I have examined, the epididymis had entirely escaped. I have never succeeded in injecting this deposit, or in tracing vessels into it. But the vessels of the testicle generally are enlarged. Pathologists have differed as to the particular tissue in which this yellow matter is deposited. Sir A. Cooper and Cruveilhier describes it to be seated in the areolar tissue between the tubuli; whilst Sir B. Brodie is of opinion, that it is secreted from their inner surface, as he discovered the yellow substance in the canal of the epididymis and also in the vas deferens which are continuous with the tubuli. I have had the opportunity of inspecting a testicle affected with this disease, in what seems to me to be its early stage from which examination I think I have been able satisfactorily to confirm this opinion. The testicle was injected with red size, and a section then made of it. The surfaces of the tunica vaginalis were partly adherent, and about three drachms of serum were collected in one part of the sac. The body of the testicle was not much enlarged: it contained, however, an abundant deposit of a firm opaque matter. Near the anterior edge of the testicle this deposit appeared in the section like round isolated yellowish-grey bodies, separated from each other by portions of the sound structure of the gland: about the centre of the organ it assumed a beaded arrangement, and towards the mediastinum formed a number of closely-set yellow lines or processes, radiating towards the posterior part of the testicle, where they were amalgamated into one uniform mass. Further examination perfectly satisfied me that this matter was lymph deposited in the tubuli seminiferi. The isolated and beaded appearances in the section resulted from breaks in the lymph thus deposited. The real seat of the effusion was very evident, from the arrangement described near the mediastinum. With a good lens some of the convoluted tubuli could be distinctly seen, filled with and dilated by the morbid deposit. A portion was carefully examined in the microscope with a similar result. The epididymis was

Fig. 650.



1, fistulous sinus leading to the suppurating cavity in the head of the epididymis; 2, concrete abscess in the tail of the epididymis.

much enlarged; its head was filled with soft concrete matter, surrounding an irregular cavity with which a fistulous sinus communicated; its tail contained a similar substance without any external opening. The various appearances described are depicted in the adjoining figure, which was taken from the recent specimen. Similar appearances to those noticed in this case have been described and figured by Cruveilhier, in his "Anatomie Pathologique."* He considers that the disease proceeds from the head of the epididymis towards the tail, and that the body of the testicle is affected only consecutively. I believe, myself, that the yellow deposit is the ordinary result of chronic inflammation of the testicle in whatever way produced; but that the peculiar appearances noticed in the case just related and likewise described by Cruveilhier, — I mean the small isolated masses in the substance of the gland, and radiating towards the mediastinum, — are only observed in those cases in which the disease originates in the epididymis, and thence spreads to the body of the testicle, and in which the part is examined before the organ has become extensively diseased. These appearances are not often seen, because it is not often that it becomes necessary to remove a testicle in such a condition, which is indeed a curable one unless complicated with suppuration. Cruveilhier supposes that this matter is effused in the areolar tissue of the testicle, and radiates along the fibrous prolongations from the corpus Highmori. I feel satisfied, however, from my own observations, that he is mistaken, and that the interior of the tubuli is the original seat of the deposit. This yellow substance has been called the *yellow tubercle of the testis*; but, as it differs from tubercular deposit, the term is objectionable and liable to lead to error. It is evidently coagulable lymph, which becomes more solid in the testicle than in most other parts, owing, perhaps, to the condensation consequent on the firm resistance offered to any enlargement of the gland by the unyielding tunica albuginea. This disease is often accompanied with effusion of serum into the tunica vaginalis, seldom amounting, however, to more than three or four ounces. Lymph also is sometimes deposited, and the sac may become partially, or totally obliterated by adhesions.

The peculiar matter effused in this disease under appropriate treatment undergoes complete absorption, the testicle being left in a condition to perform its natural functions. It sometimes happens, however, that ulceration ensues in its tunics and integuments, and that a fungous-looking growth gradually protrudes through the opening which is thus formed. This fungous growth is sometimes termed *granular swelling*; it has also received the name of *hernia testis*, being formed in a manner very analogous to that of a *hernia cerebri*, in which the substance of the brain is protruded through an ulcerated opening in the dura mater. It appears that the yellow deposit after some time excites ulceration in some part of the tunica albuginea. The tunica vaginalis, and afterwards the skin, become adherent at this spot, and likewise inflame and ulcerate. The resistance afforded by the dense unyielding tunica albuginea being thus removed, the adventitious deposit gradually presses out the tubular structure, which forms a projecting tumour consisting of the tubuli mixed up with this yellow substance, and also of ordinary granulations which spring up from the seminiferous structure. This projecting growth presents an ash or yellowish-white appearance, varied by irregular patches of a pale red hue, and sometimes of black. It is closely girt by the scrotum, the ulcerated edges of which are often thickened and everted. (*fig.* 651.)

Fig. 651.

The mass often projects so much that scarcely any part of the organ is contained within the scrotum. Though this hernial growth occurs most frequently in an advanced stage of the chronic form of inflammation, it is developed in other diseases of the organ which occasion ulceration of the tunica albuginea, and thus afford an opening for the escape of its contents. It is occasionally the result of an attack of acute inflammation supervening upon the chronic disease, and terminating in suppuration in the substance of the gland. In a case of this kind, in addition to the glandular swelling, there are sinuses more or less numerous, which burrow in the interior of the organ, and discharge pus mingled with the yellow matter. An attack of orchitis, originally acute, going on to suppuration, is also liable to be followed by a fungous protrusion of the secreting structure of the gland. In the latter case, the growth is not so exuberant, and the seminiferous structure is more distinctly apparent, owing to the absence of the yellow matter; but there are generally sinuses which furnish a purulent discharge, sometimes mixed with semen. Tubercular matter deposited in the testicle may also lead to suppuration, and the formation of a granular swelling.

A testicle after becoming somewhat enlarged from chronic inflammation, often continues indolent and stationary for years, giving rise to very little inconvenience. On examining the organ in this state, the yellow adventitious deposit is found to possess con-

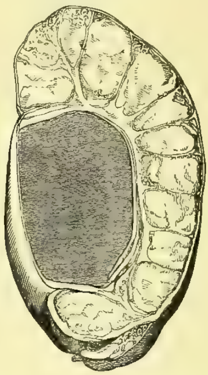
* Liv. v. pl. b., and liv. ix. pl. i.

siderable firmness and consistency; the tunica albuginea is thickened, and in some places as dense and indurated as cartilage; and the surfaces of the tunica vaginalis are closely connected by old adhesions. The glandular structure is partly displaced and atrophied by the pressure of the yellow matter; and it often happens after some time, that both undergo a slow process of wasting, so that an enlarged and indurated gland is progressively reduced, until scarcely any thing remains beyond a mere nodule of the size of a nut at which the spermatic cord terminates. I found, on examination of the body of a man who some few years previously had suffered from chronic inflammation of the testicles, both glands much indurated, but about the natural size. In both, the tubular structure was very deficient, its place being supplied by a dense fibrous tissue. At the upper part of the right testicle there was a yellowish deposit almost as dense as cartilage, and exhibiting very little trace of vascularity. In these indurated testicles the epididymis often escapes the morbid alteration affecting the body of the gland; in other cases, however, the epididymis is also found nodose, irregular, and hard. It will be perceived, from the preceding observations, that the tendency of this chronic disease is gradually to destroy the integrity of the testicle. If the inflammation be checked in an early stage, the gland is left unimpaired; if its course be not arrested until a later period, the secreting structure is partly disorganised and reduced in size; but if the disease be allowed to continue unchecked by treatment, the organ is totally destroyed, either by ulceration of its tunics and the escape of the glandular structure in the shape of a fungous growth, or by the slower process of wasting and absorption.

Syphilitic orchitis is essentially of the same nature as the chronic orchitis just described. It commonly commences in the body of the gland and rarely terminates in suppuration, or in the production of a hernial fungus. Sir A. Cooper states that in the majority of cases the disease attacks both testicles. The eight examples recorded in his work do not, however, bear out this remark; for in only two of them does it appear that both organs were attacked. According to my observation, the disease is more commonly confined to a single gland, though it occasionally affects both: this appears to be the opinion also of Ricord.* The appearances on dissection correspond with those observed in chronic inflammation.

Tubercular Disease. — In the testicle, this deposit is met with in the crude state, forming a yellow caseous substance similar to the tubercular matter occurring in the lymphatic glands. It is sometimes developed in a single mass; at other times several distinct depositions are formed in different parts of the organ: in both cases at the expense of its glandular structure, which becomes atrophied as the disease advances. The epididymis is more frequently affected than the body of the gland. In a specimen taken from a man who died of phthisis, I found the whole of the epididymis occupied by tubercular matter, with scarcely any trace of tubuli; whilst the body of the gland, though small, was perfectly sound and unaffected. (*fig.* 652.) In some

Fig. 652.



cases I have seen two, three, or more distinct tubercular deposits, separated by portions of healthy gland. This was the case in both testicles removed from a middle-aged man who died of phthisis. In some instances these isolated masses appeared to be contained in cysts formed by the processes from the tunica albuginea which separate and support the lobules. Sometimes the separate deposits seemed to be coalescing and joining together, so as to form one continuous mass; and I have found a single mass of tubercular matter surrounded by glandular structure expanded into a thin layer. In other specimens the whole testicle was occupied by a homogeneous cheesy mass, without any trace remaining of the original structure of the gland. In some instances in which the disease was thus advanced, there was very little increase in the size of the testicle; it only felt heavier and harder than in the natural state. In others, again, there was either a general uniform enlargement, or an irregular swelling at some part, commonly at the head of the epididymis. Some of these testicles, in which the disease was not much advanced, when injected made beautiful preparations, the yellow inorganic tubercular matter contrasting in a marked degree with the vermilion hue of the intervening sound portions of the organ. On several occasions I found a small quantity of serum in the tunica vaginalis, with partial adhesions and depositions of lymph. In a further stage of the disease, the characteristic deposit becomes softened down, and converted into a yellow pultaceous substance, evidently tubercular matter mixed with pus. The abscess extends to the scrotum; and after it has burst and the matter has escaped externally, cavities and sinuses are left which may be said to resemble the tubercular cavities in the lungs. The course of the disease, however,

* Traité Pratique des Maladies Vénériennes, p. 640.

in the testicle, more nearly resembles the changes which ensue in tubercle of the absorbent glands.

It has been a question whether the tubercular matter is originally formed in the areolar tissue connecting the tubuli, or in the tubuli themselves. I have certainly seen this deposit in the vas deferens near the testicle, and within the ducts of the epididymis. Dr. Carswell has given a representation of a testicle containing a multitude of pale yellow-coloured granular bodies of various sizes, which, he says, were obviously formed by the accumulation of tuberculous matter in the tubuli seminiferi. The epididymis was as thick as the little finger, and its convoluted ducts were obviously filled with a similar deposit. I believe that tubercle may be deposited in both situations, within as well as between the tubuli. Earthy matter is sometimes found in the testicle, generally in the epididymis, the part most frequently the seat of tubercle. This substance is exactly similar to the putty-looking chalky matter often observed in the lungs and bronchial glands. It is highly probable that, in these cases, the gland had at some former period been the seat of tubercular deposit, but I have not yet been able to establish this point satisfactorily.

Carcinoma. — This disease occurs in the testicle under the four forms of Scirrhus, Encephaloid, Colloid, and Melanosis.

Carcinoma seldom occurs in the testicle in the dense form which it commonly assumes in the breast. Sir A. Cooper describes a *scirrhous* disease of the testicle, in which the gland is invaded by a large white mass in lobes or tubercles. The spermatic cord is affected with a similar disease, and the glands of the abdomen become converted into a white solid texture, very unlike that of the fungoid disease. I have a man, 52 years of age, under my care at the present time, with this disease of the testicle. It forms a tumour about three times the natural size, and is almost of stony hardness, especially at the back part. There is also a large indurated tumour in the spermatic cord. This affection of the testicle is very rare, and is characterised by its slow progress as well as by its great induration.

Encephaloid cancer is by far the most frequent form of malignant disease to which the testicle is liable. When first observed, it is found in one or two masses amongst the tubuli, which gradually become destroyed as the morbid deposit accumulates. The matter is very rarely infiltrated. The testicle at this early period is extremely firm and hard, owing, not to the solid nature of the substance effused, but to the excessive distention of the unyielding tunica albuginea by the morbid growth within. The glandular structure soon entirely disappears, the whole organ being occupied by the new growth, intermixed with and sustained by the septa and fibrous processes from the mediastinum and tunica albuginea. In some instances a thin layer of the tubular structure is found expanded around a mass of encephaloid matter. At this stage the tunica vaginalis is often distended with serum; not, however, in any considerable quantity. The tunica albuginea next gives way, and a portion of the morbid growth protrudes, forming a mass projecting from the body of the gland; this sometimes occurs in more places than one. The epididymis remains for some time unaffected; but, as the disease increases, this part likewise becomes implicated and destroyed. In one instance I found the tubes in the head of the epididymis (the only part of the gland not destroyed) filled with white matter which, on microscopic examination, proved to be carcinomatous. The scrotum in a short time becomes fully distended by the diseased mass, which presents the well-known appearance of encephaloid cancer; viz. a homogeneous substance of the consistence of brain, and easily broken down with the fingers, of an opaque white colour, and variegated with patches of a pinkish hue. It is sometimes mixed with small cysts containing serum; at other times with yellow deposits of lymph, resembling that effused in chronic orchitis. These small depositions of yellow fibrine occasionally interspersed amongst the carcinomatous matter, are almost peculiar to this disease in the testicle. I have only once observed them in cancer of other parts, and that was in the kidney. As the enlargement goes on, the scrotum becomes adherent to the tumour in one or more places, then ulcerates, and allows the protrusion of the morbid mass, which projects as an open fungus. The scrotum admits however of great distention before ulceration ensues. The mass then becomes less firm, and its consistence varies very much in different parts, the morbid matter being in some a mere pulp, or resembling a creamy fluid. It is interspersed with round or irregular patches of dark looking coagula, and, when incised, often presents in different places dark minute spots of various sizes, produced by coagulation of blood in the vascular network usually mixed up with the morbid deposit. On macerating these tumours, or on pouring a stream of water on them for some time, a granular substance, the cancerous matter, is washed away, leaving behind a filamentous shreddy tissue or meshes of a delicate areolar texture, which may often be found connected to a denser fibrous substance, the remains of the tunica albuginea. The spermatic cord is often invaded by a similar substance; and in an advanced stage of the complaint, large bodies of the same kind, originating in disease of the lumbar glands, are found on the sides of the vertebræ, reaching as high up as the diaphragm.

Masses of a similar kind are sometimes also found in the lungs. The carcinomatous matter is often deposited in such abundance as to form a tumour of very considerable size; indeed, there is no other disease of the testicle which occasions solid enlargements of so great a magnitude as encephaloid cancer. M. P. Boyer removed a testicle converted into an encephaloid tumour which weighed more than nine pounds.* The vessels of the cord undergo great enlargement in this disease. In one case which I examined, the spermatic artery was found as large as the radial artery at the wrist. Cancerous germs have also been found in the blood contained in the spermatic veins. Encephaloid cancer of the testicle occurs at all periods of life: no age, indeed, can be said to be exempt from it. There are examples on record of operations for the removal of testicles thus affected, within a twelvemonth after birth. On the other hand I have met with the disease as late in life as the age of sixty-four. It more commonly occurs, however, in the middle period of life, or between the ages of twenty and thirty.

Carcinoma has, in some few instances, been found to originate from the tunica vaginalis, the glandular part of the testicle remaining for some time unaffected. Cases of the kind have been recorded by Sir E. Home† and Sir A. Cooper. The other two forms of cancer, *colloid* and *melanosis*, have rarely been observed in the testicle. A preparation of the former disease is contained in the Museum of Guy's Hospital. The organ is enlarged to four or five times its natural size, but preserves its oval form: there is scarcely any trace of the natural structure remaining, its place being supplied by colloid matter. Cruveilhier has related the case of a man who died of melanosis affecting the hand, lungs, heart, stomach, and other parts. There was a deposit of the same character in each testicle.

Cystic Disease. — The cysts developed in the substance of the testicle and constituting this disease vary very much both in number and size, and in the appearance of their contents. They may be only two or three in number, or they may exist in a countless multitude and occasion considerable enlargement of the organ. They vary in size from that of a millet seed to the dimensions of a pigeon's egg. At an early period they generally consist of smooth and slightly vascular cysts, closely adherent, and containing a transparent light-coloured fluid. In other cases the fluid is thick, viscid, and highly albuminous, and sometimes tinged with blood. I have never succeeded in detecting spermatozoa in the fluid. Sometimes a small lobulated growth arises from the walls of the cyst, and increases until it is partly or wholly filled and obliterated. The cysts usually increase at the expense of the secreting structure of the testicle, which disappears or becomes much displaced. In some instances the tubular structure forms an expanded layer over the morbid mass. When inflammation takes place, fibrine is effused between as well as within the cysts, and becomes organised; so that the tumour is partly solid and partly composed of cysts containing fluid. After some time, the surfaces of the tunica vaginalis become more or less adherent, and in old cases the tumour is intersected with fibrous bands. In several specimens of the disease I have noticed small masses of enchondroma interspersed amongst the cysts. In sections the little pearly-looking masses appear as if contained within the cysts. They are however developed between them, and are closely connected with their walls. The occurrence of enchondroma in these cystic tumours has scarcely been noticed by pathologists. There are several specimens in the Museum of the College of Surgeons.

Fig. 653.

Portion of the section of a testicle in the Museum of the College of Surgeons, with numerous masses of enchondroma between the cysts, of the exact size.
a. a. enchondroma.

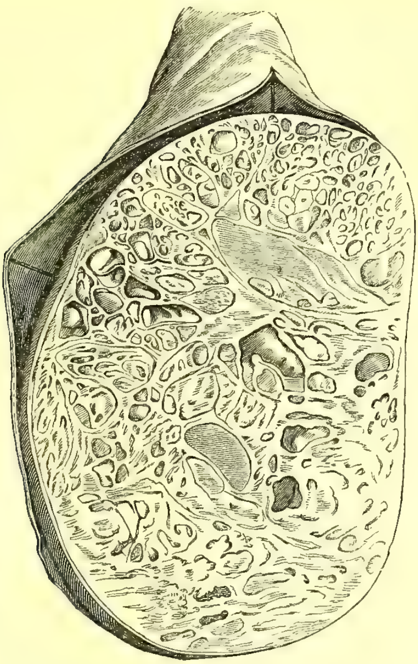
One of the specimens of cystic disease in this collection measures five inches in its largest diameter, and three inches in its smallest. Sometimes small lobulated growths arise from a part of the walls of the cyst, and increase until the cavity is partly or wholly filled and obliterated by them, in the same manner as in cystic disease of the mamma.

The mode of origin of these cysts has not been satisfactorily made out. It has been supposed that they are formed of dilated and obstructed seminiferous tubes; but as in certain cases the tubular structure exists in the form of a layer spread over the morbid mass, it is clear that the disease could not have originated in this way. This morbid change is evidently quite distinct from the little cysts so commonly developed in the head of the epididymis: indeed this part is rarely affected in cystic affections of the testicle. The disease is considered by some pathologists to be of a malignant character. After removal of a testicle thus diseased, tumours of a carcinomatous character have afterwards appeared in the lumbar glands and other parts. Mr. Cæsar Hawkins showed me several preparations of cystic sarcoma of the testicle which had been removed by operation where this happened, and it occurred also in a case which came under my own observation. The unexpected result in this instance led me to pay attention to the matter, and I am now quite satisfied that the cystic disease may be

* Revue Médicale. Nov. 1839.
† Observations on Cancer, p. 125. Anatomie Pathologique, liv. xix. pl. 3, 4.

developed under two forms. In one, it occurs in combination with carcinomatous deposit:

Fig. 654.



Section of a cystic tumour of the testicle, showing a multitude of cysts of various shapes and sizes, with solid matter interposed betwen them. The natural glandular structure is wholly destroyed.

in the other and more common form, the tumour is of an innocent character, and free from the risk of disease attacking other parts after removal of the organ. In the former the cysts are larger and less numerous than in the latter. By careful examination and with the aid of the microscope the coexistence of the two diseases may generally be made out.

Ossific deposits in the testicle. — Earthy matter occurs in the testicle under two forms: 1. Laminated, and often mixed up with cartilage; and 2., as an inorganic deposit. In the first form it is usually deposited between the tunica vaginalis and tunica albuginea, in little bony or cartilaginous patches, in which a fibrous arrangement may be recognised. I have frequently found one or two irregularly-shaped projecting ossific bodies scarcely larger than a pin's head attached to the upper part of the testicle. Ossific matter occurs also on the adherent surface of the tunica vaginalis in old cases of hydrocele, where it has been found so abundant as to form a complete ossific capsule. It has been said that the epididymis alone may be encased in bone, the testicle being free; this I have never seen. Bony matter occurs, however, in the substance of the epididymis as the result of ossification of the product of inflammation. Earthy matter in this form is not often observed in the substance of the testicle. The gland, however, when atrophied and reduced to a mere fibrous tissue, occasionally undergoes both the cartilaginous and osseous transformation. The cysts developed in the testicle, as I have already shown, are liable to similar changes.

In the second form the earthy matter is deposited in an irregular mass, containing very little animal matter; in appearance resembling mortar, and very similar to the earthy substance found in the lungs and bronchial glands. It is generally met with in the head of the epididymis, and sometimes in the lower part, and but very seldom in the body of the testicle. As I have already stated, it is most probable that this earthy matter results from the transformation of tubercular matter deposited in the testicle in early life.

Loose bodies in the tunica vaginalis. — Loose bodies are occasionally found in the cavity of the tunica vaginalis. They are small in size, and of an oval flattened shape, and their surface is smooth and polished. Their texture is in most instances elastic and homogeneous, resembling the unattached cartilages found in joints, and points of ossification are often contained in their interior. In some specimens I have observed the cartilaginous matter to be arranged in concentric laminæ. The loose body is sometimes entirely composed of bony matter. On examining a thin lamina of one in the microscope, I could distinctly see small oval corpuscules with a number of lines proceeding from them very similar to those of bone. They seldom exceed three in number, and they occur generally in combination with hydrocele, the loose bodies being the original disease.

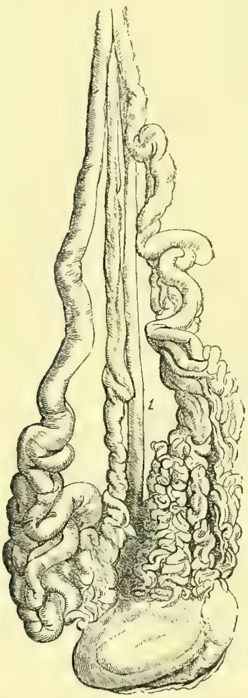
Fœtal remains in the testicle. — The remains of a fœtus have been found in some rare instances, in the scrotum, in connection with the testicle. Several examples of the kind have been collected by Ollivier (D'Angers).* In all these cases it was evident that the scrotal inclusion had succeeded to an inclusion originally abdominal; that is to say, that the organic *debris* were first situated in the abdomen in connection with the testicle, and had accompaniad the gland in its passage out of that cavity. In the cases in which the particular testicle was indicated, the right was the one affected.

Varicocele is a term applied to a morbid dilatation of the spermatic veins. On dissection they are found dilated, elongated, and more tortuous than natural, and apparently more numerous, owing to the enlargement of the smaller vessels. In an advanced stage of the disease, their coats are thickened; so that when divided the vessels remain patent, and thus present the appearance of arteries. The enlarged veins hang down below the testicle, and reach upwards into the inguinal canal; and when very volu-

* Mémoire sur la Monstruosité par Inclusion; Archives Génerale de Médicine, t. xv. p. 540.

minous conceal the gland, encroach on the septum, and extend to the other side of the scrotum. In a specimen which I carefully examined, the vessels were arranged in three clusters (*fig.* 655). One formed of the larger vessels proceeded from the inferior extremity of the testicle; the second, in which the vessels were less in size, but more numerous and tortuous, arose from the upper ex-

Fig. 655.



tremity of the testicle; whilst the third and smallest cluster surrounded and accompanied the vas deferens (1). The dilatation is not confined to the veins exterior to the gland: even those in the organ itself are varicose, and enlarged veins may often be distinctly seen ramifying between the tunica vaginalis and tunica albuginea. The veins occasionally contain phlebolites which are lodged in dilatations of the vessels. The veins of the left testicle are more subject to varicocele than those of the right. In upwards of 120 operations performed by Breschet, in only one instance was the varicocele on the right side.* Pott met with this disease on both sides of the body in only one instance. The disease, however, is far from being so rare on the right side as is generally supposed, and often exists on both at the same time, although the varicose state of the right spermatic veins is always much less than that of the left. Of the causes of varicocele, some operate on both sides, others only on one. The most influential of the former is the hydrostatic pressure consequent upon the depending position of these veins, which have to support the weight of a column of blood extending from the testicle to the second dorsal vertebra. The absence of valves is mentioned as a circumstance conducing to this disease; but this is an error, for the larger spermatic veins are always furnished with valves, though the dilatation which takes place in varicocele prevents them performing their office. There are several anatomical circumstances, which, taken together, are sufficient to explain the frequency of varicocele on the left side. On the right side the spermatic vein joins the vena cava nearly parallel to the axis of that vessel, so that the blood enters in the course of the circulation; but on the left side the spermatic vein terminates in the emulgent vein at a right angle, and in a direction perpendicular to the venous current from the kidney, which is less favourable to the return of blood from the testicle, since the two currents pursue a different direction. The left testicle hangs lower than the right, consequently the veins must be longer, and the pressure produced by the column of blood greater on the left side than on the other. The accumulation of the fæces in the sigmoid flexure of the colon previous to an evacuation tends to produce pressure on the spermatic vein, and impede the return of blood from the left testicle, especially in persons whose bowels are habitually constipated. Some persons subject to varicocele suffer from it only when the bowels are in this condition. But even the natural daily accumulation may be sufficient to produce obstruction. To this cause, we must chiefly attribute the circumstance that a varicose dilatation of the veins of the ovary in the female is nearly always confined to the left side.

In the slight degree and chronic state in which we most frequently meet with this affection, no injurious effect is produced on the testicle; but when highly or rapidly developed, the dilatation of the veins interferes so much with the nutrition of the gland as to occasion wasting. A partial atrophy of the gland, coexisting with varicocele has come under my notice in more than twenty instances; indeed, in nearly all cases in which there was a decided dilatation of the spermatic veins on one side only, the testicle of that side was the smaller of the two. In a man, aged fifty-six, with a varicocele on the left side, the testicle was so reduced that it scarcely exceeded the usual size of the organ in an infant. Some years ago, a tall sailor was under my care on account of a varicose ulcer on the left leg, who had a large varicocele on the left side, and a testicle so wasted, that it could scarcely be felt through the tunica vaginalis, which was loosely distended with fluid. The period of puberty is the time at which varicocele most commonly occurs. I have met with very few cases before that age.

Adipose tumours. — The spermatic cord may be the seat of abnormal depositions of fat. They occur at different parts, as high up

* Landouzy, Du Varicocele, p. 24.

as the inguinal canal, and as low down as the epididymis. In examining the testicles of a young man who died of pleurisy, I found a quantity of fat along the cord, and around the epididymis, and some also beneath the tunica vaginalis covering the posterior part of the testicle. In another case I met with small isolated masses of fat, coupled with a small encysted hydrocele of the cord. When developed in considerable abundance this deposit sometimes forms a tumour either in the groin or in the scrotum. A tumour of this kind in the scrotum has been mistaken for omental hernia. I once dissected a lobulated fatty tumour, surrounded by the thickened sheath of the spermatic cord, on the body of a man upwards of eighty years of age, which was very similar in appearance to a portion of omentum contained in a hernial sac. A mass of fat, however, in the cord may form a more defined and distinct swelling. Such a tumour is preserved in the Museum of the College of Surgeons. (No. 2461.) It is embedded about an inch above the testicle, in the tissues of the spermatic cord and loosely connected with them. Its shape is oval; it measures four inches in length, and consists of numerous lobes of soft fat, closely held together by their thin fibro-cellular partitions. An interesting case of large fatty tumour in the scrotum, originating in the spermatic cord, was seen by several surgeons, in 1844, much difficulty having been experienced in making out the nature of the swelling. The tumour, together with the testicle, was excised by Mr. Lawrence.* Another of the same character, but of smaller size, subsequently formed in the remains of the cord in the groin, and was excised by me in May, 1849. Collections of fat in the scrotum have been known from the time of Galen by the term *steatocele*. I suspect that they all originated from the spermatic cord.

Morbid anatomy of the scrotum. — The morbid appearances presented by the scrotum, when the seat of *œdema*, *inflammation*, and *mortification*, so closely resemble those of other parts where loose areolar tissue abound, that they require no particular description.

Elephantiasis. — This disease of the scrotum is rarely seen in Europe, but is of very common occurrence in many other parts of the globe. It consists in a morbid thickening, or hypertrophy of the tissues of which the scrotum is composed. The epidermis becomes thickened, rough as in icthyosis, and intersected with fissures, or chaps. The corium is excessively consolidated, and often nearly an inch in thickness, and very dense. The chief bulk, however, of the tumour, is formed by the conversion of the loose areolar tissue of the scrotum into a large mass of fibrous tissue, infiltrated with a thick jelly-like fluid, evidently albumen, as it coagulates on the application of heat, acid, or alochol, and sometimes on cooling after its removal from the body. The areolæ of this tissue vary a good deal in size, but some of them have been found large enough to admit the extremity of the little finger. Examined in the microscope this structure exhibits the white and yellow elements of the areolar tissue, in some instances mixed with fat cells. When the part is condensed by inflammation, there are often hardened masses in the substance of the tumour, which has a lardaceous appearance when cut, or resembles cartilage; they sometimes undergo conversion into bone. The testicles are buried in the morbid mass towards its posterior part, but they are usually sound in structure. Occasionally there is a small quantity of serum in the tunica vaginalis. In a case operated on in Calcutta, there was a hydrocele on both sides imbedded in the diseased parts, the largest of which contained between five and six pints of fluid.* The spermatic cords are elongated several inches, owing to the testicles being gradually dragged downwards during the growth of the tumour, but the cords are not otherwise diseased. In the remarkable case of Hoo Loo, a native of China, operated on by Mr. Key, in Guy's Hospital, the cremaster muscles were nearly as thick as the finger. The morbid growth is not very vascular. Its arteries are derived chiefly from the external pudic and perineal vessels; but these, owing to the magnitude of the tumour, become greatly increased in size. The veins are numerous, large, varicose, and very tortuous.

The integuments of the penis are often affected with a similar disease, and enlarge in the same ratio as the scrotum. In cases where the disease is confined to the scrotum, the penis becomes drawn in and ultimately disappears, being completely imbedded in the tumour; whilst the prepuce being elongated, opens by a navel-like aperture on the anterior surface of the tumour, as may be seen in the subjoined woodcut. In confirmed cases of elephantiasis, the tumour increases until in the course of years it attains an enormous magnitude. As this takes place, the skin is borrowed from the lower part of the abdomen, so that the hair on the pubes becomes thinly scattered on the front and upper part of the tumour. The tumour assumes an oval or pyramidal form, the apex being superior, and is attached to the body by a thick peduncle extending from the pubes, occupying the whole of the perineum, and terminating posteriorly at the verge of the anus. There is scarcely any limit to the size which the tumour may attain. It has been known to acquire such a magnitude as to weigh more than two hundred pounds†, exceeding the weight of the rest of the body. It has been found to measure more than four feet in cir-

* Vide accounts of this case by Lawrence, Medical Gazette, May 30. 1845; by Brodie, Lectures on Pathology, p. 271.; by Edwards, and myself, in Provincial Med. and Surg. Journal, June 25. 1845.

* Calcutta Quarterly Journal, No. 3.

† Case cited from Ephémérides d'Allemagne, by Larrey. Mémoires de Chirurgie Militaire, t. ii. p. 115.

cumference, and almost to reach the ground when the patient is in the upright position. In a case operated on by Clot Bey in Egypt, the morbid mass, which weighed one hundred and ten pounds, kept the patient's legs far apart, and obliged him to remain constantly on the ground; it was so bulky that he could even sit upon it. In the accompanying figure

Fig. 656.

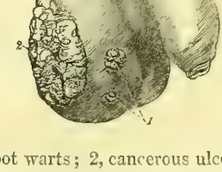
of a black man, affected with elephantiasis, taken from Dr. Titley's work on "Diseases of the Genitals, in the Male," the tumour descended nearly to the ankles.

Elephantiasis of the scrotum is a morbid affection of the integuments, analogous to the enlargement of the extremities commonly known by the name of *Barbadoes leg;* with which, indeed, in those countries where the disease is prevalent, it is liable to be combined. Elephantiasis of the scrotum, however, grows to a greater size and makes more rapid progress than the same disease in the leg, owing to the very loose texture and depending state of the parts. The labia pudendi of females in warm climates are subject to a similar change, though not to the same extent nor so frequently as the scrotum. This disease appears to be the result of a low form of inflammation of the veins, and to be analogous to the affection termed *phlegmasia dolens.* It is preceded by febrile attacks, attended with pain and heat in the part, and swelling and tenderness of the glands in the groin. After a time, the scrotum continues to enlarge, independently of febrile attacks. In December, 1847, I saw a gentleman, from Barbadoes, who had this disease in the early stage. The whole scrotum was considerably enlarged, forming a doughy inelastic swelling, fissured in two or three places. A portion of skin at the root of the penis was a little red and puffy as if affected in a slight degree. The glands in the left groin were enlarged, but those on the right side were unaffected. The testicles were sound.

Hypertrophy of the scrotum is an affection of the same nature as the knotty and lobulated growth of the skin occasionally observed on the nose and in other parts. In this disease the integuments appear as if composed of lobes divided by fissures. In the Museum of St. Bartholomew's Hospital there is a preparation of this kind, but no history is attached to it. The hypertrophied scrotum appears to have been removed during life. Many years ago I saw a case of the kind at the hospital of La Charité in Paris. The patient was a young man whose scrotum was hypertrophied to about four times its natural size. This disease is liable to be confounded with elephantiasis, but differs from it in the circumstance that the morbid enlargement is entirely confined to the skin, the subcutaneous areolar tissue being unaffected.

Cancer Scroti, or, as it is commonly called, *chimney sweeper's cancer*, is a disease of the skin, which attacks the scrotum of persons who have been exposed to the contact of soot. It is originally developed in the form of a small pimple or warty excrescence, termed *soot-wart*, which often remains on the scrotum for months or even years without undergoing any change. Usually, there is only a single wart at the lower part of the scrotum; sometimes there are two or three of different sizes; and occasionally they are so numerous and so abundantly and largely developed as to form a considerable cauliflower excrescence. After a time the wart becomes soft, excoriated and red, and exudes a thin irritating discharge, which becoming dry forms an incrustation over the excrescence. After the scab has been picked off, or rubbed off by friction against the dress, ulceration ensues, destroys the wart and produces a painful chronic sore, possessing the ordinary characters of a carcinomatous ulcer on the skin, — thick, indurated and everted edges, and an irregular excavated base, the surface of which discharges a thin sanious fluid. The ulcer, if suffered to proceed, in-

Fig. 657.

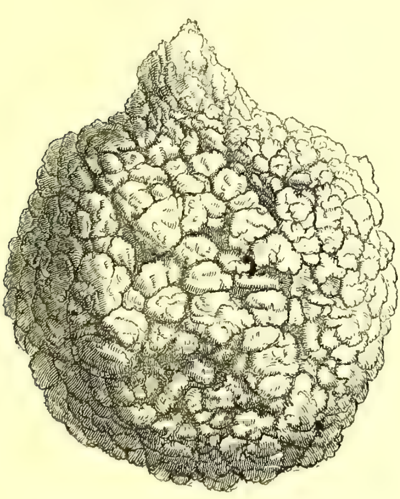


1 small soot warts; 2, cancerous ulcer succeeding the wart.

creases widely, invading the whole scrotum to the perineum, and laying bare the crura penis. At the same time it penetrates deeply to the tunica vaginalis, which becomes firmly connected to the morbid scrotum and adherent to the testicle. This organ may also become involved in the disease, and be the seat of a deep excavated sore. The glands in the groin often enlarge at an early period from irritation; but at length they become indurated and diseased. The inguinal glands sometimes suppurate, and form intractable ulcers in the groin similar in character to the sore on the scrotum. The ulcer spreads towards its circumference widely and superficially, whilst in the centre it burrows deeply until in many instances it reaches the great vessels of the thigh, destroys their coats, and causes death by hæmorrhage. In other cases the glands remain unaffected, but ulceration advances slowly in the direction of the cord, and a frightful sore is produced.

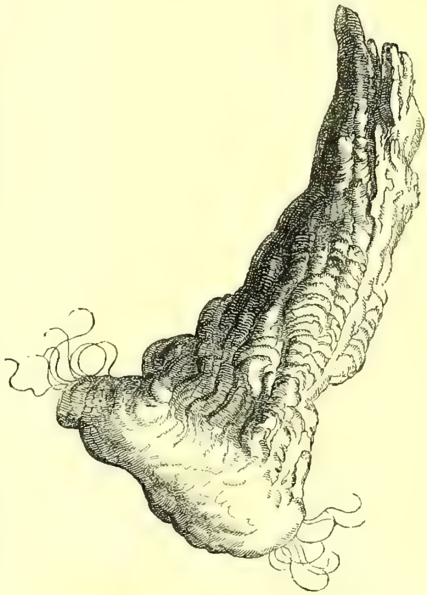
The small excrescence in which cancer scroti usually originates is soft, vascular, and sensitive; and in many respects similar to the soft warts which occur on the internal membrane of the prepuce and on the glans penis. The soot-wart appears, in fact, to consist of a congeries of morbidly enlarged papillæ. The Museum of the London Hospital contains a remarkable specimen of chimney-sweeper's cancer, in which nearly the whole scrotum is occupied by a cauliflower excrescence, which exhibits these papillæ in a very advanced state of developement. It was removed from an old man, about sixty-four years of age, who afterwards left the hospital cured. The morbid growth is composed of a number of projecting processes densely grouped together, of variable size, but many very large, with their summits lobulated, expanded, and elevated on narrow peduncles, more or less flattened. They are represented in the subjoined engraving. The soot-wart is sometimes covered with a dense and thick concretion, formed

Fig. 658.



by successive layers of incrustation, the superficial still remaining attached, so as to form a projecting elongated conical process, which is not unlike the spur of the cock, and when very long is occasionally twisted like the horn of a ram. Some curious excrescences of this kind are represented in the clever etchings of Mr. Wadd.* The subjoined figure taken

Fig. 659.



from one of them, exhibits the process of its exact size.

Upon dissecting a portion of scrotum affected with chimney-sweeper's cancer, the part is found to present very similar appearances to those of carcinoma of the lip. The tissue at the base of the ulcer is dense, indurated, and distinctly laminated, and possesses very little vascularity. On examining some matter scraped from the base of a soot-wart shortly after its removal from the body, I perceived a number of caudate and spindle-shaped nucleated cells. Epithelial cells have likewise been observed in several cases, and the disease is regarded as belonging to the epithelial form of cancer. On examining some diseased glands in the groin in a case of scrotal cancer, I found them enlarged and indurated, and composed of a whitish brown or yellowish white substance, mixed up in some places with a soft curd-like matter, or greyish pus, contained in thin white cysts.

Carcinoma scroti is, with few exceptions, confined to chimney-sweepers; and the irritating action of the soot on the skin of the scrotum is no doubt its exciting cause. A similar disease occasionally occurs in other parts of the skin, but the scrotum being seldom cleansed and well adapted to harbour soot

* Cases of Diseased Prepuce and Scrotum, pl. x. xi. xii.

seems more exposed to the disease. Sir James Earle has related the case of a man who had a large sore resembling chimney-sweeper's cancer which reached from the bend of the wrist to the knuckles, occupying almost the whole of the back of the left hand. The man was a gardener, and for several springs had been in the habit of strewing soot on the ground round the young plants to preserve them from slugs. He carried the soot in an old garden pot which hung on his left hand, while he strewed the soot with his right.

The predisposition to cancer scroti appears in some instances to be hereditary. The late Mr. Earle extirpated the testicle and diseased integuments from a sweep aged thirty-five, a patient in St. Bartholomew's Hospital, whose grandfather, father, and one brother had all perished from the effects of the disease. A father and son were once in St. George's Hospital at the same time on account of it. Mr. Cusack mentions that he removed a soot-wart from the hand of a female who carried on the business of chimney-sweeping, and that he had previously excised an excrescence of the same nature from the ear of her son.*

Cancer scroti occurs more commonly at the middle period than at any other time of life. In the majority of cases which I have met with the disease occurred between the ages of thirty and forty. Those exposed however to the action of soot may become affected at a much earlier period. Mr. Wadd has figured a diseased prepuce and soot-wart on the scrotum from a boy aged fifteen; and Sir J. Earle witnessed a case of the disease as early as at eight years of age. It appears that the seeds of this malady are sown in early life, but in general do not germinate until they have remained for some time dormant in the system. What is the permanent effect on the scrotum produced by soot, which thus renders it in certain individuals so peculiarly susceptible of a cancerous action at some distant period, we cannot explain; but that the soot, though the exciting cause of the disease, may in some instances be a remote one, is shown by several striking facts. It is known that persons who have been sweeps when young, but have abandoned the occupation, have afterwards been attacked with chimney-sweeper's cancer, although they have long been removed from all contact with soot. A sailor between forty and fifty years of age, was admitted into the London Hospital, with an ulcerated sore on the scrotum, presenting all the characters of genuine chimney-sweeper's cancer. The inguinal glands were indurated and enlarged, and subsequently ulcerated. He had been brought up as a sweep; but for the last twenty-two years, during which period he had served at sea, he had not been employed amongst soot in any way whatever. The disease first appeared in the scrotum about three years before. In this case, therefore, the injurious influence of soot must have been exerted nineteen years before the appearance of disease, during which long period he was entirely removed from the effects of its exciting cause. It has sometimes happened, after the morbid parts had been completely extirpated, and the wound healed, the patient having avoided further contact with soot, that the disease has re-appeared as it were afresh, a second and even a third time; not, however, in the cicatrix of the wound, but on a different part of the scrotum. These, and similar facts, lead to the conclusion that though abandonment of his occupation may render the adult chimney-sweeper less liable to cancer, it by no means forms a satisfactory security against its occurrence.

Cancer scroti chiefly extends its ravages by affecting the contiguous tissues, and has little disposition to contaminate the lymphatic glands or distant parts. An instance is on record of an old chimney-sweeper, who had been subject to this disease for forty years, and had undergone three operations for its removal, yet even then the glands in the groin were unaffected.* A man aged fifty-one who had been a chimney-sweeper ever since the age of seven years, was a patient of mine on account of this disease. He had been repeatedly attacked with it during a period of twenty-two years, and had submitted to no less than five operations for its removal. The glands in one groin became affected only a few months previously. Ulceration took place, and the patient died from its irritative effects on the constitution. On a careful examination of the body, no trace of internal disease could be detected. The cancer was strictly limited to the groin and scrotum. Mr. B. Cooper has likewise recorded a case of chimney-sweeper's cancer which ended fatally; and on examination none of the glands or viscera of the interior of the body were affected.† These cases show that, when the inguinal glands are indurated, they may be excised with a fair hope of a successful result.

Melanosis. — Notwithstanding the dark colour of the skin of the scrotum, melanosis is an exceedingly rare affection of this part. Indeed, the only case of its occurrence there with which I am acquainted, is one that happened in my own practice. The patient was a cabinet-maker, aged thirty-two, and the disease commenced as a small dark spot, apparently produced by some black deposit beneath the epidermis, raising it a little above the surrounding surface. This spot increased until it formed a fungous growth. I excised the part, but the disease re-appeared in the scrotum and in the glands of the groin six months afterwards. It made, however, very slow progress, and did not destroy the patient for six years.‡

* Dublin Journal of Medical Science, vol. xxi p. 137.

* Mr. Hawkin's Lecture on Tumours. Lond. Med. Gazette, vol. xxi. p. 842.

† Lond. Med. Gazette, vol. xliii. p. 532.

‡ Vide Report of the Case in Lond. Journal of Medicine, vol. i. p. 220.

Fibrous tumours. — A small fibrous tumour is occasionally developed in the areolar tissue of the scrotum. It may acquire the size of the testicle, and being firm and of an oval form, resembles a supernumerary gland. I have met with only one case of this form of tumour. Dr. Mott, of the United States, excised an enormous mass from the scrotum of a man about seventy-three years of age. The scrotum was twelve to fifteen times its ordinary bulk, and was filled with tumours of a stony hardness, from the size of a nutmeg to that of a large pea. The tumours had all a very white appearance, and the integuments over two or three of the largest, having been ulcerated for upwards of a year, poured forth a fœtid discharge, together with a white substance resembling mortar. The disease was upwards of twenty years' duration. I have no doubt this disease was originally of a fibrous character. The calcareous matter and other changes resemble those occasionally observed in large fibrous tumours of the uterus. A tumour of a similar character and of great size was removed by operation from the scrotum of a man in St. Vincent's hospital, Dublin, by Dr. O'Ferrall.*

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(*T. B. Curling.*)

THORAX (θώραξ from θορέω to leap, because in it the heart beats). "The habitation of the breathing parts." — That part of the human body destined to contain the lungs and heart, and by its movements to maintain the function of respiration.

Generally by the term *thorax* is understood a cavity set apart for the respiratory organs. Such a cavity, however, is not essential to respiration: a respiratory surface only is essential. This must exist in every animal, whilst a separate thorax is found perfect only in mammalia.

The development of the respiratory surface may take place in three ways.

1st. Either towards the *interior* of the body, in the form of ramified or sacculated cavities; or,

2ndly. Towards the *exterior*, in the form of lamellated, ramified, pectinated, tufted, ciliated, or pinnated processes called "*branchiæ*," in which Nature seems to have exhausted all imaginable varieties of form; and,

3rdly. By a system of tubes ramified to extreme fineness, either in an especial cavity or thorax, or in a cavity common to these organs and to others destined for the digestive function.

The movements necessary to respiration, are modified according to the form of the respiratory apparatus and the nature of the medium to be respired, whether pure air or air contained in water.

In some of the lowest animals, the respiratory movements are the same as those of locomotion, as in the monad and other infusorial animalcules. In all animals, even when the respiratory organs are contained in a true thoracic cavity, the frame-work serves other purposes besides that of drawing in and throwing out air; it gives attachment to the largest muscles of the upper extremity, whether prehensile or locomotive. In man particularly, we find the respiratory muscles contribute to such acts as coughing, sucking, sneezing, yawning, sighing, singing, vomiting, as well as the innumerable articulate sounds of language.

Distinct respiratory movements, as dependent upon alternate contractions and dilatations of a thoracic cavity, are most regular, or at least, they have been more noticed, in mammiferous animals. The thoracic cavities of mammiferous animals have much of the mechanism of respiration in common. They all possess a vertebral column or spine, and that peculiar frame-work of ribs, together with a sternum, so articulated together as to move in breathing.

There is likewise a great similarity of muscular arrangement around the thoracic cavity; and consequently the respiratory movements closely resemble each other.

Although the boundaries of the thorax are generally the parts which move in respiration, and these are generally composed of vertebræ ribs and sternum, yet some animals may have either all of these, or they may lack some of them, or, if present, they may not move in the breathing function. *Frogs* have a sternum, but no ribs; *serpents* have ribs, but no sternum; *tortoises* have ribs, vertebræ, and

* Dublin Hospital Gazette. Feb. 1845

sternum in one mass, rigid and immoveable: the *crocodile* and *lizard* have perfect ribs, but their sternum is almost entirely cartilaginous; and, lastly, in man, the components of the thoracic cavity may have a mobility to command or exceed a space equal to the whole cavity allotted for the respiratory organs. The relative quantity of air which he can respire for the aëration of his blood is probably greater than in any other animal, and his movements are more under the control of his will, and are greatly influenced by mental emotions.

Classification of the Respiratory Movements in Animals. — It is not easy to name any particular part in the perfect thorax of the higher vertebrata, which is equally destined for respiratory motion throughout the class. Commonly with ribs and intercostal muscles, we connect the idea of a thorax, or a breathing chamber for respiration; but a fish has ribs, and likewise intercostal muscles, yet not for any of the purposes of respiration, nor do we acknowledge them to belong to its thorax. A frog has a thorax for respiration with internal lungs, but no ribs, nor, consequently, any intercostal muscles. Nor is a diaphragm necessary to thoracic respiration; for it is mostly absent in birds and reptiles, and quite rudimentary in the few instances (such as the ostrich, crocodile, and chelonia), in which it is met with. In the chelonia neither ribs, spine, nor sternum are concerned in the respiratory movements.

The movements of respiration tend to bring before some surface, air or air contained in water; or to bring a certain surface continually into a fresh medium, In whatever way this may be accomplished, whether by moving the whole body, or part of the body to and fro, such movements, likewise, are not uniformly for the mere purpose of respiration, i. e. the mere purpose of aëration. All reptiles take more air into their capacious lungs than they require for oxygenating the blood, particularly in the aquatic kinds (as in the turtle), where the air serves to buoy up their heavy and slow-moving bodies in the dense element they inhabit. Serpents are provided with numerous highly-moveable ribs and powerful intercostal muscles, capable of rapid and extensive inspiration and expiration. They can perfectly distend their body with air. The same may be observed in the chameleon. These volumes of air cannot alone be subservient to respiration, as it cannot all come into contact with the simple undivided respiratory sacs. We see, therefore, there is no necessary relation between the quantity of air an animal may inspire and the extent of respiratory surface. The long hissing sound which serpents produce to alarm their prey, is effected by the expulsion of this great volume of air, by their ribs, through the narrow passages of the nostrils.

In the higher mammiferous animals, we find respiration more especially destined for the chemical purpose of oxygenating the blood. Hence a more limited quantity is taken in, and it is speedily thrown out again. Large animals make fewer respirations than small ones. According to Scoresby*, the whale breathes four or five times a minute; the dog, the cat, and rabbit, from twenty to thirty in the same period; and in small birds the respirations are remarkably rapid.

Whatever be the form of the aërating organ, "breathing" is accomplished either by, 1st, the weight of the atmosphere rushing into certain cavities, because certain parts of these cavities dilate and threaten a vacuum; or, 2ndly, by the direct projectile or collapsing force of an organ *throwing* the ambient element onward. These two ways are generally more or less combined in the same animal. Nor does there appear to be any relation between the grade of the animal and the order of respiratory movement obtained. We notice in the respiration of man a regular inspiration and expiration, two currents in different directions; and in the lowest animal, the connecting link with the vegetable kingdom, the porifera, or sponge tribe, there are likewise two respiratory currents by distinct channels, which are as regular as the motion of rivers from their source to the ocean, or any other movement depending upon the established order of things. In some species of medusæ, there are peculiar sacs on the inferior surface of the body, which, during the expansion of the body, admit water through certain apertures, and again expel it during the succeeding contraction, representiug a perfect inspiratory and expiratory action. The complexity, therefore, of respiratory movements does not correspond with the increasing development of the breathing organs. Those animals which have an internal sacculated lung, always retain a certain quantity of the breathing element in "*reserve*" within their system; whereas those animals which have external lungs, or gills, have no "*reserve*" respirable medium. They need none, because where there is an external lung, the ambient element answers the purpose of the "*reserve*"; it is always in contact with the breathing surface. This "reserve," in mammalia, &c., is not, probably, so necessary to aëration as for the purpose of ejecting any matter which may obstruct the air passages — or, in more popular language, for "coughing" up any matter out of the throat.

The different kinds of respiratory movement may be arranged as follows; —

1. Infusorial Animalcules	By projectile force.
2. Insects - - -	Uncertain.
3. Fishes - - -	By vacuum & projectile force.
4. Amphibia - -	do. do.
5. Birds - - -	do. do.
6. Mammalia - -	do. do.

Of the First Kind of Respiratory Movement. Infusoria.— These animals breathe by a stream propelled in one direction, produced by the ra-

* El. Physiol. Wagner, 8vo. 1844, p. 670.

pid vibration of hair-like organs — cilia. (Vid. Art. CILIA.)

Of the Second Species of Respiration. Insects.— The breathing apparatus in insects generally reaches a high degree of development. Sometimes respiratory tubes or tracheæ penetrate every part, in the form of minute ramifying vessels conveying the included air to all the organs. The moving power or means of the renewal of the air in these tubes is at present little known. Some insects, although they live in water (as, for instance, the water beetles, and also water spiders), retain a bubble of air around them ; and, according to Nitzch*, they renew the air in the irtrachæ by alternately elevating and depressing the antennæ. Beetles, before flying, seem to *inflate* themselves with air, so as to unfold their wings, which, like other parts of their body, are supplied with air tubes. In this case an inspirative effort must be made by some cavity. Under certain circumstances, bees emit a voice, a shrill sound, which is independent of the motion of the wings, and which appears to be connected with the existence of a current of air through the respiratory tubes or tracheæ; at least, such has been observed when the animal has been irritated and immersed in water, the surface of which, where it was in contact with the orifice of the stigmata at the root of the wing, evidently vibrated at the moment the sound was produced.†

In the *orthoptera* particularly, there are distinct respiratory movements, alternate dilatations and contractions of the abdomen ; in fact, respiratory motions are more distinctly perceptible in this division than in any other insects. In the *locusta verrucivora* particularly, it is easy to distinguish how the abdominal rings, which have smaller abdominal scuta between them inferiorly, are alternately *elevated* and *depressed* exactly like ribs. If we smear the great thoracic stigmata with oil, we find that numerous bubbles of air escape from it during these motions.

The organs of respiratory motion, by means of which the supply of air is renewed, present many points of uncertainty. On the one hand, where large stigmata are placed opposite to each other, and connected by tracheæ, it is easy to see that alternate opening and shutting of their valves may produce a current capable of renewing the supply of air. It is conceivable also, how, in the orthoptera, lepidoptera, and others, the expansion and contraction of the body, and the elasticity of the air-sacs contained in it, may cause the ingress of air. It is less obvious, however, how the same effect is produced in caterpillars and the larvæ of beetles, where a current of air cannot very easily arise from the opposite position of the stigmata, on account of the minute ramifications of the tracheæ ; and consequently we must look for some peculiar mechanism, probably cilia, unless we are disposed to admit the stagnation of the air in its vessels. Hence it has been conjectured that the dilatation and contraction of the dorsal vessel contributes to this purpose. This, however, appears to be scarcely possible ; and it might be asked on the contrary, if the vermicular motion of the body itself, the sliding of its segments upon each other, are not the means of keeping up the constant ingress and egress of air.*

In the lowest of the molluscous class, the external tunic with which they are covered is generally so elastic, that it is capable of dilating by its own properties, when it has been greatly contracted by the muscular coat that is within; and in forcible expirations, Dr. Grant has observed these animals to contract their muscular coat, and to retract the exterior covering, so as to propel, with considerable impetuosity, and to a distance, the water that fills their respiratory cavity. The elasticity of the tunic tends to overcome the resistance of the muscular coat, and to expand, to a certain extent, the respiratory cavity. Without, therefore, the existence of elastic ligaments, such as we find in conchifera, there is a partial means of enlarging the respiratory cavity given to these tunicated animals. This, however, is only in occasional, forced, respiration ; constant and alternate contraction and expansion of the exterior tunic is not met with in any known tunicated, nor in a conchiferous animal.† The streams that enter the respiratory, and pass out of the anal aperture, are smooth, regular, and incessant, and are produced by ciliary movement.

Of the Third Species of Respiration. Fishes. — It may be said that the thorax of fishes usually presents four elastic cartilaginous arches, which *approximate* and *separate*, open or close the gills, at the same time *increasing* or *diminishing* the capacity of the so-formed thorax. These ribs, or branchial arches, support the gills, which are covered by a great flap (operculum) on each side of the base of the skull.

The respiratory current enters at the mouth, passes through the fissures on each side of the fauces, and escapes through the branchial openings, placed laterally, covered by the moveable operculum. This stream is uniformly in one direction, — from before, backwards. It might be asked, why does not the water rush in by the branchial opening when the mouth "threatens" a vacuum ? It will be observed that the margin of the operculum, or great lateral flap, is edged with a delicate membrane, which acts as a valve, this, by the pressure of the water, is forced close round the lateral openings : thus, the water, upon the expansion of the jaws, is prevented entering behind, and consequently rushes in towards the gills by the mouth ; the jaws now close, the operculum immediately opens by the

* On the Respiration of the Hydrophilæ, in Reil's Archiv. B. x. S. 440.

† Hunter, Philosophical Transactions. 1792. p. 182.

* Reimarcus, Ueber das Athmen. in Reil's Archiv. B. xi. S. 2.; and Nitzsch, Comment. de Respirat. p. 39. et seq.

† Grant's Lecture "On the Respiratory Organs of Invertebrata." Lancet, 1833—4, vol. i. p. 964.

force of the jaws contracting with the mouth full of water, which contraction, or expiration, forces the water through the branchial arches and ultimately out by the lateral openings.

Thus the respiration is of a mixed order. The first stage by atmospheric and hydraulic pressure; the second stage by direct muscular force, similar to that of swallowing.

If we cut off the delicate fringe around the operculum the fish is suffocated, the operation being analogous to puncturing the human thorax.

Fishes also possess a power of regulating their respiration. We have watched fishes when in a quiescent state move their respiratory organs so gently that the motion was nearly imperceptible, and at times quite so; but if at such times you alarm the animal, respiration becomes vigorous, and a comparatively vast body of water rushes past their respiratory organs. The same may be likewise observed when fishes have remained long in a small quantity of water, as if the respiratory movements became more and more vigorous with the deterioration of their element, but give them a fresh supply of water and respiration becomes quiescent again.

Of the Fourth Species of Respiration. Amphibia.— In this class there is a gradual development of the animal formation from an aquatic to an aërial being; so likewise is the aqueous gradually converted into aërial respiration.

The respiration of some of these animals is indeed most curious, — curious as to the very limited quantity of air necessary for their well-being, and curious as to whether they have this limited quantity supplied regularly or otherwise. For instance, you may keep an aquatic turtle out of water for days, and it will keep constantly respiring air; immerse it in water, and it will remain below the surface for half an hour, or an hour, without any inconvenience, and some of these animals will breathe at the surface during the day, and sleep at the bottom *all* night without once rising for air, while during the day the same animal cannot remain below above half an hour without showing signs of discomfort. And again, the common tortoise during hybernation breathes so small a quantity of air, that we have never been able to form any calculation of the quantity then respired.

In frogs there are no ribs by which the lungs may be moved; consequently there is no vacuum formed by their thorax during respiration; they fill the lungs like the tortoise, the newt, the chameleon, &c., by the working of their jaws; or, in other words, they swallow their air just as we swallow our food. In this respect their respiratory movements resemble those of fishes; the first process being through the agency of external pressure, by making a vacuum with the mouth; the second, that of *forcing*, by the operation of the pharynx. They resemble mammalia in having an internal lung, retaining the air for some time, and in expelling it through the same channel by which it entered. The respiration of the frog has gained attention, and is hence better understood than that of many other animals of this class. The following is the mechanism of its respiration, as described particularly by Townson *, though before noticed by Swammerdam and Malpighi. When the broad lingual bone which forms the floor of the mouth is drawn down from the palate by its muscles, the air of the mouth is rarefied, and an additional quantity enters by the nasal apertures, which admit of being closed by valves. The lingual bone is then raised, the nasal apertures are closed, and the air is now *forced*, or rather swallowed, through the rima glottidis into the pulmonary sacs, and can also fill the laryngeal pouches which open into the mouth. Expiration is produced partly by the pressure of the abdominal muscles, and partly by the peculiar muscular power of the pulmonary parietes. To the careless observer the frog does not appear to breathe: it is never seen to open its mouth; there is no motion of its sides like breathing, and when it is provoked (or rather through fear), though it still keeps its mouth close shut, its sides and back rise, and it blows itself up apparently by some internal power. Upon observing it more narrowly, that skinny and bag-like part of its mouth which is under the jaw, is seen to be in constant motion. While this bag is dilating and contracting, the mouth is *never* opened to take in new air, but it seems to live all the while on one mouthful of air, and seems to be playing it backwards and forwards between the mouth and lungs. If we now observe the nostrils, a twirling motion, which lets in air at each movement of the jaws, is apparent, corresponding to the quantity of air inspired. If we keep the mouth open we presently see the animal struggle for breath, for we by this means disable the forcing apparatus from propelling the required air into the lungs.

The newt breathes with the jaws and nostrils like the frog. It has, like the frog, a constant motion, by short strokes of the bag under the jaw. This bag is formed by the membranes of the mouth, covered and moved by the genio-hyoid and mylo-hyoid muscles. Every minute, or less, it stops, as if intending some particular motion; then gradually the bag swells out under the lower jaw to a great size; the contained air is then pressed down into the lungs, and in proportion as the jaws are emptied, the sides of the animal are swelled up. The toad, the chameleon, and the green lizard breathe in the same way, *propelling* mouthfuls of air down into the lungs. The chameleon can force down a greater or smaller quantity of air, as its needs or fears prompt it. At times it seems to fill its body almost to bursting with air. The tortoise, like the frog, holds its jaws close, and swallows the air; alternately depressing and elevating the hyoid bone. The first of these motions permits the air to enter the nostrils, when, the tongue immediately closing their internal aperture, the second motion forces the air into the lungs. It is not un-

* Tracts and Obs. on Nat. Hist., &c. London, 1799.

common to notice tortoises yawn; but how different is their yawning from that of man, who makes, at that time, a deep inspiration, while, in the tortoise, respiration is impossible. We are not prepared exactly to say how the tortoise and turtle expire; but probably the expiration is performed by the contraction of the abdominal muscles between the lower shield or plastron and the posterior extremities; for either of these animals can at will, when alarmed, forcibly expel air with a hissing sound, although its shell is unyielding.

The most remarkable respiratory movement we have noticed, has been in the common turtle. Sometimes this animal will swell out his hard case, the sternum or plastron yielding to some internal force; but it is difficult to say by what means this is distended and *kept distended.*

It is clear this animal can gorge itself with air until it cannot sink in water, and that at pleasure it can disgorge itself and fall to the bottom, where it lives upon only a fraction of the quantity of air it had just previously expelled.

Of the Fifth Species of Respiration. Birds.—Here we have a contracting and dilating thorax, with ribs and sternum. The cavity of the chest is not divided by a diaphragm, but is common to the whole digestive organs as well as the lungs; or, as is said, they are "all chest and no belly." They differ from all other animals in this respect, that the lungs do not hang in the cavity of the trunk as unattached sacs, but are attached in the form of flattened masses, of spongy, bright red, cellular texture, to the posterior side of the thorax, reaching to the pelvis. They have vesicles or âir bags extending through the whole body; and the cancellated structure of their bones is connected with the true lungs; so that if we tie the trachea and amputate the wing, leaving the stump of the bone exposed, the bird can inspire and expire through the humerus. In the same manner that the diffusion of air through all parts of the body in insects makes the highest extent of respiration in invertebrata, so also is it with birds among the vertebrata.

The sternum and ribs, together with the immoveable range of dorsal vertebræ, all contribute to dilate and narrow the thorax, after the manner of a bellows movement. This dilatation and contraction draws the air *through* the true lungs, which never move, and immediately the air cells are expanded. By this means two conditions are obtained; the air is drawn through the lungs for aëration; and the air filling the cancellated structure, renders the bird specifically lighter.

The high flying rapacious bird can thus by a respiratory movement attenuate the air in his body, when soaring in the atmosphere, and again at pleasure condense it in every interstice of his frame, when he drops like a cannon ball, to pounce on his prey; but immediately before seizing it, again he attenuates the air within him to break his fall; otherwise he would be dashed to pieces upon the pointed crag, and die along with his victim.

This beautiful provision is wholly due to his respiratory movement, at one time acting as a condensing, and at another time as an exhausting syringe.

Of the Sixth Species of Respiration. Mammalia.—In this class we first meet with a perfect muscular septum (diaphragm) forming the two cavities of the trunk; the one for the lungs, and the other for the abdominal viscera. All animals which have a diaphragm, maintain respiration in a manner similar to each other; for, indeed, it appears that the only use of this muscle is to maintain a movement of air —that unceasing pumping to and fro of inspiration and expiration. Their respiration, or at least their *inspiration*, is purely of the vacuum order.

The diaphragm is the chief muscle of ordinary breathing. It can act with great power, protruding the viscera, by its descent, at each ordinary inspiration. This is strikingly seen in animals recumbent and at rest, as in the cow, horse, goat, dog, &c., when it appears, as if the animal was breathing with its abdomen. The ribs likewise in some degree maintain respiration in the lower mammiferous animals, particularly in disease. For instance, the respiration of the horse or dog, when the lung is emphysematous, or what is familiarly termed "broken-winded," is costal, and at such times the respiratory action of the ribs may be beautifully seen.

It is most probable that in mammalian respiration we have the highest order of *accommodation* for peculiar respiration, according to the condition of the animal; i. e. an instinctive power to respire by different parts of the thoracic cavity, according to the needs of the animal, whether modified by health or disease.

Nearly two hundred years ago, Lower changed the respiratory movements of the dog from diaphragmatic to costal, by paralysing the diaphragm through the medium of the phrenic nerve. (*Phil. Tr. Abr.*, vol. i. p. 179.)

The respiration of mammalia is the bellows action — inflation of the lungs by expansion of the thorax, or inspiration by vacuum, and expiration by propulsion.

The projectile force in the respiration of mammalia is nearly all due to mere elastic contractility; i. e. ordinary expirations are produced by the elasticity of the lungs and ribs, returning backwards, or collapsing, after their distension by the inspiratory muscles. This mere dead and involuntary force performs one half of our respiration.

Man is not distinguished either by the force, extent, or complexity of his respiratory movements; he is exceeded in all these particulars by inferior animals. The roar of the lion gives the idea of an overwhelming expiratory power; nor are his lungs less complicated; and the vibration of thousands of cilia, promoting currents around the monad, is more complex than the simple respiratory thoracic action of mammalia. The most striking difference is that produced by mental influence, which appears to command the most delicate modifications of this movement, so indicative of the passions of his mind, while in the lower animals we see none of these.

Of the Thorax in Man. *Anatomy of the framework of the Thorax.*—A portion of the spine, the ribs, the sternum, together with numerous muscles, form the wall of the human thorax. The framework of bones is so arranged as to admit of free mobility in various directions, so as to increase or diminish the cubic capacity of the thoracic cavity.

Of the Dorsal Vertebræ.—That portion of the spine which enters into the composition of the thorax consists of the dorsal vertebræ, which are 12 in number, intermediate in size and position, between the cervical and the lumbar vertebræ. They form the main pillar of support for the whole respiratory apparatus —the great fixed point for the chief respiratory muscles to act against or draw upon. Their general appearance is that of increasing in size from above downwards; but when carefully examined, they are as two cones, the apices of which touch at about the fourth or fifth vertebra, from which point, in either direction, they increase in their dimensions; their breadth laterally exceeds their depth from before backwards. Their bodies are large and project deeply into the cavity of the thorax, diminishing greatly the antero-posterior diameter of the chest. Out of twenty cases, the average projection is $2\frac{3}{8}$ of an inch, leaving little more than 4 inches for the heart and great blood-vessels.

A deep sulcus is thus formed, which if a cast be taken of the cavity of the thorax, is very striking. In phthisis pulmonalis, the space between the bodies of these vertebræ *and the sternum* is sometimes *less* than one inch! When the thorax changes its form by disease, this centre pillar is liable to wedge in or jam up the thoracic organs against the walls of the chest.

The vertebræ are connected to each other by ligaments, and jointed beautifully into each other, so as collectively to admit of extensive motion, while there is but little movement between any two vertebræ.

Of the bonds of union, the most remarkable are the *inter-vertebral disks* (*ligamenta inter-vertebralia*—Weitbr.)—composed of fibro-cartilage, and placed between the bodies of the vertebræ, each disk serving to unite two vertebræ, and yet to permit a motion in any direction, yielding on that side towards which the column inclines, while on the contrary side it expands with the increasing intervertebral space. This substance is to the brain what the cushion or "buffer" between each railway carriage is to the traveller; it breaks a sudden jar from being transmitted from carriage to carriage. So does this intervertebral substance soften down any sudden jerk received at the lower extremity of the spine, preventing its being transmitted to the brain in the varied actions of walking, running, and leaping.

Of the Sternum (*os pectoris: Xiphoides*), so named from στέρνον, the breast: is a kind of flattened bone, symmetrical in shape, which occupies the anterior and middle part of the thorax. It is supported by the ribs on either side; it is broadest at its upper part, and then narrowed; it widens again, and finally becomes compressed and narrow where it joins the ensiform cartilage. (*Fig.* 660, *e.*) Its direction is oblique from above downwards and forwards. This, with the curvature backwards of the spine opposite to it, increases the antero-posterior diameter of the thorax, as may be seen in a lateral view of a cast of the thoracic cavity.

The length of the sternum, which is proportionably smaller in the female than the male, varies from 5 to $7\frac{1}{2}$ inches. At the upper part its breadth is from $1\frac{1}{2}$ to 2 inches.

Its thickness above is about 6 lines; at its lowest part it is much thinner, never exceeding three lines. The ancients compared the sternum to the sword of a gladiator; and hence have arisen the denominations given to its various parts: as the handle (*manubrium*), the body (*mucro*), the point, or xiphoid appendix, (*ensiformis*); but the last mentioned part now only retains the designation grounded on this circumstance. This division of the bone into three parts has been retained by some modern anatomists, who describe the three pieces of the sternum separately, as so many distinct bones; we shall only adhere to this in speaking of the development of the bone.

In anatomical language it is said, the sternum presents two surfaces, two borders, and two extremities.

Of the anterior or cutaneous surface of the Sternum.—This is subcutaneous, slightly convex and affords attachment to the aponeurosis of the pectoralis major and the sterno-cleido-mastoid muscles. It presents three or four transverse projecting lines, which are traces of the original division of the bone into five pieces. The union between the 1st and 2nd pieces corresponds to the insertion of the 2nd costal cartilage, and is frequently cartilaginous even in the adult age. The line which marks the union of the first two pieces of the bone is the most remarkable: it causes a projection of variable size in different individuals, which has been sometimes mistaken for a fracture or exostosis. At the lower part we sometimes find a *foramen;* sometimes in place of the foramen there is a considerable aperture, to which much importance has been attached, as affording a proof of the primitive separation of the bone in the median line. (*Fig.* 660. *d.*) The existence of this opening explains how purulent matter deposited behind the sternum may, in certain cases, make its way outwards without any absorption of the bone. This bone is covered by a strong interlacement of very numerous aponeurotic fibres.

Of the posterior (*mediastinal or cardiac*) *surface.*—This is slightly concave, and parallel in direction to the anterior surface. The concavity is directed downwards and backwards, towards the cavity of the thorax, and gives attachment superiorly to the *sterno-hyoideus* and *sterno-thyroideus* muscles, inferiorly to the *triangularis sterni.*

Along the middle line, this concavity corresponds with the interval left by the divergence of the two pleuræ (anterior mediastinum).

In the young subject, transverse lines are seen corresponding to those which occupy the anterior surface; all of these, except the two between the first and second pieces of the bone, are effaced at a more advanced age. This surface is in relation with many organs contained in the chest, and especially the heart, in front of which the sternum forms a kind of shield. This is exemplified, as already noticed, in the *frog*, which is provided with a sternum, though it has no ribs. At the lower part of the sternum are many nutritient foramina.

Of the borders of the Sternum. — These are thick and marked at each side by seven angular depressions for the reception of the cartilages of the first seven ribs, which gives this bone a notched and serrated appearance. These angular cavities are separated from each other by semilunar notches, which are longer above than below, where the facettes closely approach each other. The uppermost of these seven cavities is shallow, triangular, and at an early age becomes ingrained with the cartilage of the first rib; those which follow are deeper, angular, and situated at the extremities of each of the transverse lines. When examined in the dried specimen, they appear more angular and deeper in proportion to the youth of the subject.

Of the clavicular extremity.—This is slightly convex, and is the broadest and thickest part of the whole bone. It is slightly excavated from side to side, and presents at each corner a depression for the reception of the sternal end of the clavicle, which bears the name *fourchette;* this is surrounded with irregularities for the insertion of ligaments. It frequently happens that the two clavicular articulations are not at the same height; a fact which was noticed by Morgagni, and which Cruveilhier attributes to the unequal wearing of the two articular surfaces. We have once seen the clavicular articulation so low as to unite with the first costal cartilage.

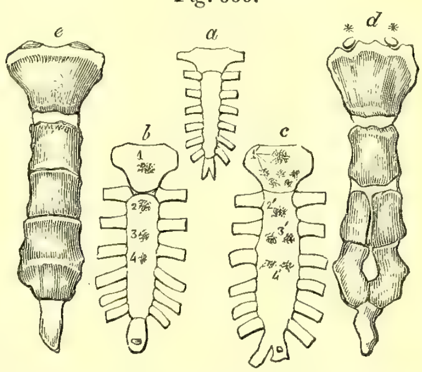
Of the inferior extremity of the Sternum. — This is formed by the *xiphoid* appendix; or *ensiform* cartilage, for it often remains cartilaginous to adult age. In length, shape, and direction, it presents numerous varieties; it is frequently bifid, sometimes pierced by a foramen, and is occasionally bent forwards, or to one side, and in certain cases much depressed: its summit gives attachment to an aponeurotic structure, called the *linea alba;* behind, it indirectly corresponds with the stomach, which rests upon it when the body is placed in a prone position.

Connections. — The sternum articulates with fourteen ribs through the medium of their cartilages, and more directly with the two clavicles.

Structure of the Sternum. — This bone consists of two very thin compact laminæ, with an intervening cancellated structure, the cells of which are very large and have very delicate parietes. It is one of the most spongy bones of the body, and it is more than probable that to this circumstance the frequency of disease in it may be attributed. Absorption of this bone and great displacement by bending inwards is very common, particularly in women who wear tight stays. Under such circumstances, or by disease, we have witnessed the sternum so depressed inwards that the depth, including all the thoracic integuments from the spinous processes of the dorsal vertebræ to the anterior surface of this bone, did not exceed three inches, instead of from seven to nine inches.

Of the Development or Ossification of the Sternum. — As far as the middle of fœtal life or a little later, the sternum is altogether cartilaginous, as represented at *a*, *fig.* 660. This

Fig. 660.



bone is one of the slowest in its ossification; it exhibits no bony points or centres of ossification up to the sixth month of fœtal life. It is also of all bones the one in which the phenomena of ossification proceed with the least regularity. After the sixth month of fœtal life, ossification begins with the formation of osseous granules in the middle of the intervals between the points at which the cartilages of the ribs are connected.

"There are five of these granules for the sternum, exclusive of the ensiform appendage, and they form as many pieces (*e*, *fig.* 660.). The process of ossification makes its appearance in the first between the fifth and sixth months; and, soon following in the second and third, it reaches the fourth at the end of fœtal life. The osseous centre of the last varies considerably in the time of its appearance. It may be found soon after birth, and may not be visible for a considerable time (one or two years) after that period."

"In many cases, one or more of the divisions of the sternum are formed from more nuclei than one, and there are peculiarities with respect to the number and position of these additional granules which require notice."

Ossification of the 1st piece.—This sometimes presents a single nucleus (*fig.* 660, *b* 1.), rounded and transversely strong; sometimes it presents two nuclei, and in this case they may be either placed one above the other, or side by side. In the former case the uppermost nucleus is the larger; in the latter, both may be symmetrical and of equal size, or what is more common, they may be of unequal magnitude. It may occasionally present more than two osseous points. Albinus found three in one subject, and four in another.* Mr. Quain has a preparation in University College, where the very unusual number of six (*fig.* 660. *c.* 1′.) are to be seen. In this case, where there is a plurality of osseous points, the largest are generally situated alone; exceptions to this rule are very rare.

Ossification of the body, or the 2nd, 3rd, 4th, and 5th pieces.— The osseous nuclei which enter into the composition of the body of the sternum have generally a rounded form when they are single, and are situated in the middle line; where they are in pairs or are placed laterally, they are more elongated, but smaller, and appear to represent only the half of one of the single nodules. The second piece has not often more than a single granule (*b.* 2, *c.* 2′.), but the rest are frequently formed from two nuclei, which are placed laterally to one another (*c* 3′, 4′.), and not vertically as occurs in the first piece.

These different osseous points are always so arranged as to be situated between two costo-sternal articulations, so that a portion of the sternum is developed in each of the intervals comprised between the ribs. The last piece is the only exception, being common to the articulation of the 6th and 7th ribs. There are, therefore, four primitive pieces of the body of the sternum (*b.* 1, 2, 3, 4.), and each of these is sometimes formed by one point of ossification; at other times by two lateral points. The first piece may be formed of one or many ossific points, which may be arranged vertically as well as laterally To the centres of ossification here described, M. Brechet † has added two small epi-sternal granules, whose position is sufficiently shown by the indication of them, *fig.* 660. at *d***. They occur only at rather advanced periods of life, but they do not appear to be constant.

Union of the points of ossification of the body of the Sternum.—In considering the union of the different parts which compose the body of the sternum, it is necessary to make a distinction between the *lateral* conjunction—that is, the union of the osseous points which are situated on each side of the median line—and the *vertical* conjunction, or the union of the pieces of the sternum properly so called. The *lateral* conjunction, or the union of these osseous germs, which form a pair in the same interval, always precedes the *vertical* conjunction.

The *vertical* conjunction, or the union of the different pieces of the body of the sternum together, commences with the two inferior portions. After this union, the body of the bone consists only of three parts. The 2nd piece then unites with the lower: the sternal foramen is formed sometimes at the junction of these last mentioned parts, sometimes at the place where the two lateral points of the 4th and of the 3rd portions of the body are united. If the interruption to the progress of ossification should occur at the point where the lateral parts of two sternal pieces would meet, the foramen is likely to have considerable size; for it may be the result of an "arrest of development" proceeding from four centres each constituting a part. (*Fig.* 660. *d.*) The union of the divisions of the body of the sternum takes place precisely in the inverse order of their appearance In fact the appearance of the osseous points proceeds from above downwards, while their union proceeds from below upwards: a fact which verifies the assertion, that the order of development of osseous points is not always correlative to the order of junction.

The lowest or 5th piece is joined to the 4th soon after puberty; the 4th and the 3rd are united, between 20 and 30 years of age; and the body of the sternum is usually not completed by the junction of the 3rd piece to the 2nd before 35 or 40 years. Lastly, the 1st division does not in general join the rest of the sternum at any period; but should its union happen to take place, it is only to be met with in advanced age.

Of the ossification of the appendix.—This is generally accomplished by one nodule. Sometimes there are two; and then they are rarely symmetrical. The process commences in the upper part of the cartilage, and very rarely extends through the whole. The time of appearance of the osseous point is extremely variable. Sometimes it is visible towards the 3rd or 4th year; sometimes not until the 12th or even the 18th year; according to the observation of Béclard, between the 2nd and 18th years.

From the 40th to the 50th year, and sometimes later, the appendix becomes united to the body of the sternum. From the varieties of ossification or development of the sternum, it will be evident that it is impossible to assign to it a limited number of osseous points.

Of the Ribs.— The ribs (*Costæ* from *custodes* *) extend from the dorsal portion of the vertebral column to the sternum, forming arches which correspond to the lateral segments of the chest. About one sixth of the ribs are cartilaginous, and the rest osseous. The osseous portion is the *rib* properly so called; the cartilaginous portion is named the *costal cartilage*.

The ribs are 24 in number, 12 on each side; but cases occasionally occur in which this number is augmented by the addition

* Cruveilhier, Descrip. Anat. 8vo. 1840. Lond. p. 87.

† Recherches sur Différentes Piéces du Squelette des Animaux Vertébrés, &c. in "Annales des Sciences Naturelles." 2de Serie, t. 10. (Zoologie) p. 91.

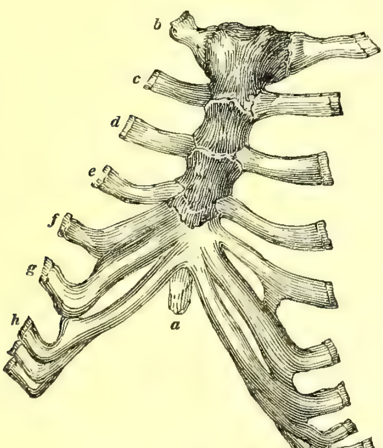
* As if they were guardians of those principal organs of the animal machine, the heart and lungs. —Munro: The Anatomy of the Human Bones. p. 234. Edingb. 1726.

of a pair of cervical or lumbar ribs: in this case the supernumerary ribs are formed from the anterior parts of the transverse processes of either the seventh cervical or first lumbar vertebra; which affords a strong proof of the analogy existing between a transverse process and a rib. Sometimes the usual number is diminished to 22: this is more rarely the case. When this occurs, we sometimes find two adjacent ribs united throughout their entire length. Sometimes the first rib is in a rudimentary state, being properly formed posteriorly, but having its anterior extremity lost among the muscles, or united to the 2nd rib. Mr. Quain has lately seen an instance in which this diminution of the number of the ribs was accompanied with the absence of a dorsal vertebra.*

Classification of the ribs.— The ribs are numerically designated 1st, 2nd, 3rd, and so on, counting from above downwards. In the living or in the undissected subject it is easier to count the ribs from below upwards.

The seven superior ribs are united by means of their own cartilaginous prolongations (*fig.* 661. *b*, *c*, *d*, *e*, *f*, *g*, and *h*; and *fig.* 662.)

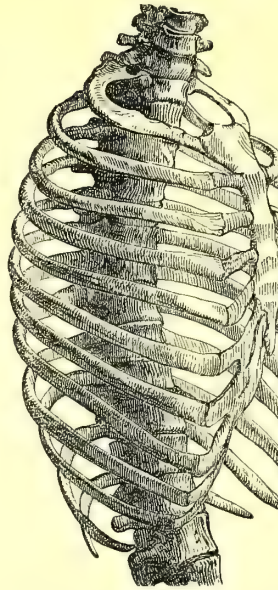
Fig. 661.



to the sternum, and are called *true ribs* or *sternal ribs*, or *vertebro-sternal ribs*; the remaining five are not so immediately prolonged to the sternum, and are denominated *false ribs*, or *asternal ribs*, or *vertebral ribs*.

We think it would be more judicious to classify them otherwise, and consider the *five* superior ribs as *sternal*, *true*, or *thoracic ribs*; the *five* next inferior, as *diaphragmatic ribs*; the *two* last, being *floating* or *false ribs*. Because, the first five especially encompass the cavity of the thorax; the five next a portion only of this space, together with a large portion of the abdominal viscera; and, lastly, because the two last do not touch the sternum through the medium of any cartilage. The transverse shade (*fig.* 682.) represents the arch of the diaphragm, or the floor of the thorax. Every rib articulates with the dorsal vertebræ;

Fig. 662.



Position of the ribs and spine after deep expiration.

the spine is their fixed point, or centre of motion,— the main pillar upon which they act. The superior ten ribs articulate through the medium of cartilages, the first seven through the medium of their own, the next three through that of those of their superior neighbours, (*fig.* 661.) with the sternum.

The ribs have certain *general* characters which distinguish them from all other bones; and likewise certain *proper* or *special* characters, by which one is known from another.

I. *Of the general characters of the ribs.*—The ribs resemble flattened bony hoops, varying in breadth from ·4 to ·7 of an inch, and from ·1 to ·4 of an inch in thickness; they once attain a maximum, and twice a minimum length (*fig.* 662.)

They are of a very irregular shape. Their arch or curve is neither uniform relatively to each other, nor yet relatively to itself at different parts of the bone; moreover they are twisted in different degrees upon themselves so that the two extremities of the same bone point in different directions, and cannot simultaneously touch an horizontal surface.

Surfaces. — These bones present two surfaces: an *external* or *cutaneous* surface, which is convex and smooth; and an *internal* or *pulmonary* surface, which is concave and likewise smooth. The anterior end is comparatively flat, the posterior is more cylindrical and truncated, and is rough, particularly at the extremity.

Borders. — The ribs have two borders, the one superior, and the other inferior. The superior border is smooth and rounded, and gives attachment to the intercostal muscles;

* Elements of Anatomy by Mr. Quain and W. Sharpey, M.D. London, 8vo. 1843, p. 105.

the inferior border is more thin and sharp, particularly in the middle third, or body, of the bone. This thin or blade-like appearance is caused by a groove on its inner aspect termed *sulcus costalis*, which is commonly said to be for the lodgment of the intercostal vessels: this border also gives attachment to the intercostal muscles. The borders are irregular in their direction corresponding with the shape of the rib; which we shall presently notice.

Fig. 663.

Fourth rib.

Extremities. — (a) Posterior or vertebral extremity. (*fig.* 663. *c*). — This is rougher and somewhat thicker than the other parts of the rib, and is hence denominated its *head* (*capitulum costæ*). It presents, except in instances to be presently stated two articular facets, a superior and an inferior one, separated by a well-defined ridge. Each of these facets articulates with a corresponding small surface on the bodies of two vertebræ, the ridge just mentioned corresponding with the intervertebral substance.

The head of the rib is supported by a narrow round part, somewhat constricted — the *neck* (*fig.* 663. *f*). This is flattened from before backwards and is the weakest part of the bone. Behind the neck there are some inequalities, which correspond to the transverse process of the dorsal vertebra below, Externally to the neck is an eminence known as the *tubercle* of the rib (tuberosity, *tuberculum costæ*, *fig.* 663. *g*), which is smooth in one part for its articulation with the transverse process of the lower of the two vertebræ to which the head is connected, and rough in the other, which is posterior, and in some ribs superior to the above, for the insertion of the posterior costo-transverse ligament. The tubercles are most prominent in the four or five superior ribs. Anterior to the tubercle the rib suddenly bends forwards, leaving this part the most convex, making what is termed its *angle.* (*fig.* 663. *h*) The interval which separates the tuberosity from the angle, is the thickest, roundest, and strongest part of the bone.

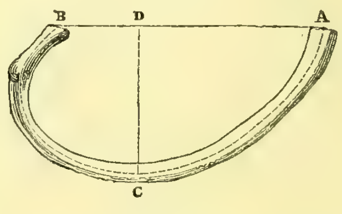
(b) Anterior, or sternal extremity (*fig.* 663. *d*). — The anterior extremity of the ribs is broad, flat, and deeply hollowed out at its tip into an oval pit, into which is implanted the costal cartilage. This extremity of the rib is broader and thicker than it is an inch more posteriorly.

Body. — This may be described as that part intervening between the angle and the anterior extremity. We have stated that the posterior end is more round than the anterior; the body, therefore, may be considered as of a transition form, passing from the cylindrical to the flat, blade-like, shape as it approaches towards the sternum.

Curve. — The curve which the ribs follow is very irregular, and therefore not easy to describe. No doubt they are of the form best adapted to admit of a great increase of thoracic capacity at the expense of a remarkably small movement. They appear to encompass the thorax in a somewhat spiral manner (see dark lines *figs.* 682 and 683.); to accomplish which they have three curves, one the common general arch or bend of the bone; the others the twist of the edges near the extremities termed the *curve of torsion.*

(A) *Arch or general bend of the ribs.* — This is the most remarkable feature of a rib. Whatever be the curve of the 1st rib, it may be said that each inferior rib describes a curve "one size" larger; so that one rib can be laid close within the other, like hoops of gradually increasing sizes. Two distinct curves will then be seen. It will be observed that the part extending between the head and the angle describes a larger circle than the angle itself, which as the name implies, is the most acute turn in the bone. More anterior to this, the curve becomes remarkably large; which Haller has so expressively described as representing the tangent to the posterior curve. In connexion with the general curve of the rib should be noticed two linear measurements, viz., the chord and the versed sine. In *fig.* 664. is given

Fig. 664.



Second rib.

the 2nd rib; the line A B is the chord, and D C the versed sine, or a line extending from the chord to the most prominent part of the bend of the bone. The general curve regulates the length of the versed sine.

This curve of the rib gives the sides of the chest a power of enlarging, — a lateral mobility, — according to the length of the versed sine, and quite distinct from the antero-posterior enlargement. which is according to the length of the chord. The ribs do not increase the lateral dimensions of the thorax by abduction, but solely by their rotation upon the line A B

(B) *Curves of torsion of the ribs.* — If we take the 7th rib and place it on a table it will be observed that the extremities cannot simultaneously rest upon one plane, because it is twisted upon itself. This is due to what is called the *curve of torsion.* The rib is twisted at each end; hence a posterior and an anterior torsion. The posterior torsion is most conspicuous, and is therefore more commonly noticed.

(*a*) Posterior torsion. — This torsion is marked at the angle of the rib (*h*, *fig.* 663.), particularly upon the convex surface, by an oblique line or a series of faint lines directed from above downwards and forwards. Like other features of the ribs, it passes through gradations, being scarcely perceptible in the 2nd rib, more so in the 3rd, and increasing to the maximum in the 8th, in the 9th and 10th it quickly decreases, until it is lost in the 11th and 12th. The greater the torsion the more distinct is the angle; where the angle is rudimentary the torsion is imperceptible, as in the 11th and 12th ribs.

The degrees of this torsion as it passes through the ribs are most distinctly seen by having the ribs separate, and placing them on a flat surface with their superior edge uppermost, arranging them so that they do not quite touch each other, when the heads of the different ribs will stand up at different heights from the table, forming a somewhat regular wave. This is solely produced by this posterior torsion.

(*b*) Anterior torsion. — Near the anterior extremity, on the convex surface, in well-developed ribs, we observe an oblique line analogous to that at the angle of the rib, but much less distinctly marked. This line may be considered as forming the anterior angle and corresponding torsion of the ribs, which, like the posterior, is intended for more favourable muscular insertions. Although the anterior angle is comparatively feebly marked, the anterior torsion of the ribs is as well defined as the posterior torsion. It will be seen in *fig.* 667, that while the posterior extremity of the rib curls *upwards*, the anterior extremity curls *downwards*. In like manner as we notice the posterior torsion by placing the separate ribs on a table, so may the anterior torsion be as strikingly seen, taking care to place the ribs upon their *superior edge* so that the sharp inferior edge is turned upwards. The anterior ends will be seen to stand up in different degrees from the table according to their torsion, commencing with the 3rd or 4th and terminating with the 10th rib.

Articulations of the ribs. — The ribs are articulated behind with the dorsal vertebræ, and in front with the sternum through the medium of the costal cartilages. This has already been noticed under *Extremities of the ribs.*

Position of the ribs. — The ribs are arranged more or less obliquely, — about midway between the perpendicular and horizontal (*figs.* 662. and 683.); — and they somewhat diverge from each other as they approach the sternum. (*figs.* 662. 680. and 681.) Not one of them is horizontal, though commonly represented as if they were. Their position is given in *fig.* 662. This is important to remember, because we shall see that costal breathing altogether depends upon their obliquity.

Structure. — The compact and spongy substances are so distributed throughout the whole length of the ribs that they possess a certain degree of flexibility, with great power of resistance. In young subjects the compact substance is in excess; in the aged, and in certain diseases, the opposite is the case; hence the extreme fragility of these bones, which are then broken by the least effort.

Development. — The ribs are amongst the earliest developed bones, ossification commencing in them even somewhat before it has made its appearance in the vertebræ. The deposition of osseous matter extends rapidly throughout them. Each rib (with exceptions to be noticed) is formed from one principal piece; and two epiphyses. Of these two epiphyses, one forms the head of the rib, and the other the tubercle: their ossification commences between the sixteenth and twentieth years of age; and they are united to the rest of the bone a few years after, — about the twenty-fifth year.

II. *Special characters of different ribs.*—The differential characters of the ribs, when minutely examined, are well marked; for, strictly speaking, no two ribs on the same side are of the same shape and dimensions. Although the difference is very small between two contiguous ribs, as, for instance, between the central ribs, *i. e.* between the 6th, 7th, and 8th, yet it is very conspicuous between those of the top compared with those of the bottom of the thorax. Whatever be the peculiarity under examination, we find it most developed in the 6th or 7th rib; and below this it becomes less and less marked, until, in the 12th rib, it appears rudimentary. In fact, the 12th rib may be considered little more than a prolonged transverse process; but not so with the 1st rib, which possesses all the marks and uses necessary to the character of a rib.

The ribs differ in their length, and in their chord and versed-sine measurements, and consequently in the area of thorax which they encompass. The thoracic dimensions vary considerably in different men and in the two sexes; yet the relative measurements and weight of the ribs will be found useful to our comprehending more perfectly the respiratory movements.

These relative measurememts are from a well-formed male thorax. The area-measurement is calculated from an internal cast of the thorax, cut up slice by slice through each intercostal space. These slices were traced upon paper and measured, giving the absolute area of thoracic cavity encompassed by each pair of ribs, their cartilages, and the sternum. (See *fig.* 668.)

Table A.—Relative Lengths and Weight of, and Area of Thoracic Space encompassed by, the respective Ribs, including the Space made up by the Sternum and Costal Cartilages.

Rib.	Absolute Length.	Chord Length.	Versed Sine	Area Sq. In.	Weight, Grains.
1	5·25	2·00	1·75	10·	98
2	9·00	3·75	3·00	27·	134
3	11·00	5·10	3·40	40·	181
4	12·25	6·00	3·50	51·	255
5	12·50	6·90	3·50	57·	308
6	12·60	7·10	3·50	63·	317
7	12·25	7·50	3·30	58·5	391
8	12·10	7·90	3·25	43·	363
9	11·50	7·75	3·10	27·	280
10	10·50	7·00	2·90	20·	216
11	8·25	5·90	2·25	10·	145
12	4·50	3·75	1·00	7·5	60

Fig. 665. represents the above table by curves. The perpendicular lines represent the ribs; and the curves the characters referred to. By a general view it will be seen that all the lines curve upwards, and are at their highest at about from the 5th to the 9th rib. We shall not treat of *particular* ribs, but of certain characteristics as they run through the ribs. A knowledge of their shape is necessary to comprehending the respiratory movements in diagnosing thoracic disease.

1. *Length.* — The length of a rib may be taken in three ways, — its absolute length, chord length, and versed-sine length.

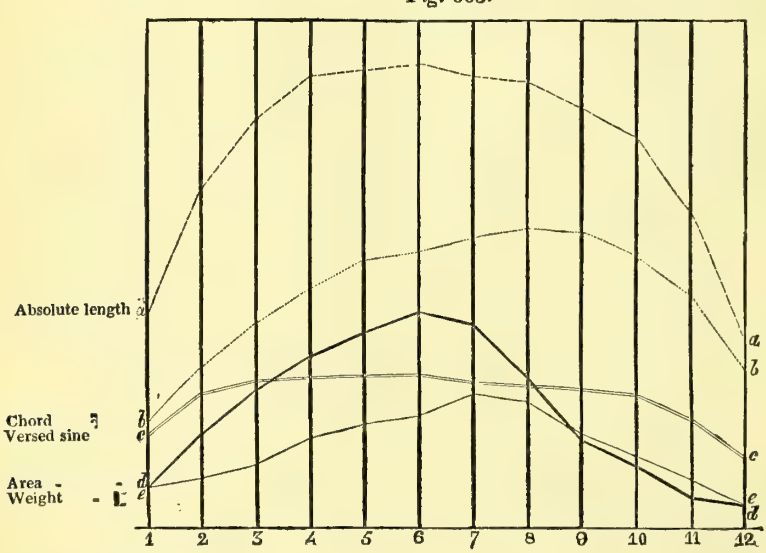
(a) *Absolute length.*—In the length from the anterior to the posterior extremity, (A C B, *fig.* 664.) the 12th rib is the shortest. The 11th rib is nearly double the length of the 12th rib; likewise the 2nd rib is nearly double the length of the 1st rib; therefore the 1st and 2nd, and the 11th and 12th differ more remarkably in their length than do any of the other ribs. The length (curve *a*, *fig.* 665.) suddenly increases up to the 4th rib; and then the difference is trifling to the 8th rib; after this the shortening is as rapid as in the four superior ribs.

(b) *Chord length.* — The dotted line *b*, *fig.* 665, represents this measurement. This length from tip to tip (A B, *fig.* 664.) of the rib is the chief modifier of the different apparent mobility of particular ribs. If we allow the range of *costal* movement to be the same in each rib, while each succeeding rib increases in its chord length, the *apparent* mobility in different ribs will increase exactly as their chord measurement increases. If a rib be three inches long, and if its free extremity by a given movement passes through one inch of space, the free extremity of a rib six inches long will, with the same absolute movement, pass through two inches. The chord length is an important element in modifying thoracic capacity. It is in this measurement that the 1st rib is the shortest and nearly one half the length of the 2nd rib, — as 2· is to 3·75. (Table A.)

The chord length (line *b*, *fig.* 665, compare with line *a*,) increases and decreases less abruptly than that of the absolute length.

If we were to admit that all the ribs at their fulcra possessed the same extent of motion, still the antero-posterior length of the thorax would be unequally increased, and that exactly in relation to the chord measurement;

Fig. 665.



and hence the 7th, 8th, 9th, and 10th ribs would advance most. It is a fact that in deep inspiration the lower part of the sternum advances most, somewhat representing the curve line *b*, *fig.* 665.

(c) *Versed Sine Length* (D C, *fig.* 664.) —

As the chord length is to the antero-posterior movement, so is this measurement to the lateral movement of the thorax. This is the most uniform measurement in the ribs. If the 1st rib be 1·75, the 2nd rib is to that as 3; and from this rib to the 9th rib, the versed sine never exceeds 3·5; hence the curve *c*, *fig*. 665. is more horizontal than any of the other curves. So likewise it will be found that the *lateral* enlargement of the thorax in deep breathing is more uniform than the antero-posterior enlargement. (See dotted line, *figs*. 711, 712. compared with dotted line, *figs*. 713, 714.) The space gained by the ribs rotating must be strictly in relation to the length between the deepest part of the arch and the chord line. (D C, *fig*. 664.) This measurement is greatest relatively in the 2nd rib, and absolutely smallest in the 12th rib, the curve here being very small.

The versed sine of the ribs corresponds with the great curve: if a rib were not curved at all, there would be no versed sine. The versed sine does not increase after the 4th rib; and the curvature of the first four ribs forms smaller circles than the rest. The 5th and 6th ribs, although rapidly increasing in absolute length (see Table A.), yet present nearly the same versed sine; and while the chord line increases up to the 9th rib, from the 6th to the 9th the versed sine decreases, showing that the circle or arch of the rib becomes larger as we descend, until the 12th rib, which describes the greatest curve and the shortest versed sine.

In fact there is little difference in the versed sine length from the 3rd to the 10th rib, as described by the double line *c*, *fig*. 665. This difference of arching of the ribs constitutes the conical form of the thorax, the smaller circles being at the apex, and the larger at the base of the cavity.

(2) *Weight*. — The ribs increase not only in their various measurements but also in their weight up to the 7th or 8th where they attain their maximum development. The faint continuous curve, *e*, *fig*. 665. is the line of the relative weight.

(3) *Torsion of the ribs* (*special characters*). —We have already mentioned that the ribs have two torsions, an anterior and a posrerior. No rib is entirely free from this twist. It is incorrect to believe that the 1st rib is without any torsion, and therefore that the whole rib in its length can touch the same plane. In fact the 1st rib may in one sense be looked upon as the most twisted of all the set, inasmuch as the flat sides which are internal and external in other ribs are in this rib inferior and superior.

Like other features, the degree of torsion in the different ribs is progressive towards a maximum, and then towards a minimum. The 2nd, 11th, and 12th ribs are most devoid of torsion. In the last two ribs the torsion appears less than it really is, because of their shortness and the large circle which they describe.

The two torsions in each rib are always in contrary directions, except in the 2nd rib, where they are both downwards, but the torsion is here very slight. In the 1st rib, as in the ten inferior ribs, they are in contrary directions to each other, so that its two ends cannot touch the same plane at the same time; but its anterior and posterior torsions are respectively contrary to those of the ten inferior ribs; its posterior torsion being, like that of the second rib, downwards, and its anterior upwards.

The relative torsion of the ribs may be expressed by giving the respective elevations of each extremity from the plane upon which they rest. Thus the posterior torsion is seen when the rib rests upon its *inferior* edge, and the anterior torsion when it rests upon its *superior* edge. In this way the following table is calculated.

Table B. — Torsions of the Ribs.

Ribs.	Posterior End Torsion Upwards.	Anterior End Torsion Downwards.
1	6·0*	5·0†
2	2·5*	3·0
3	3·0	3·0
4	12·5	4·25
5	13·0	12·0
6	12·25	21·5
7	18·00	29·5
8	21·25	28·0
9	21·25	25·0
10	9·50	17·5
11	1·50	5·5
12	2·00	4·5

If the posterior twist of the ribs upwards be expressed conjointly as 114, the anterior torsion downwards is 153; therefore the anterior torsion is greater than the posterior. The torsions in the 2nd, 3rd, 11th, and 12th are the least; and they are the greatest in the 7th, 8th, and 9th ribs. Moreover as the torsion increases at one extremity of the rib, for the most part it increases at the other likewise.

The ribs of some persons are much less twisted than those of others. This is particularly the case in young subjects before the age of puberty. In infants the torsions are imperceptible; therefore they increase as we advance to maturity. These torsions afford more favourable traction for the muscles. Where the respiratory movement is most apparent, as from the 4th to the 9th rib, the torsion is highest.

The posterior torsion gives the ribs, when placed in their natural position, a very oblique direction with reference to the spine. This is very important to remember; for the more oblique, the more favourable are they for mobility or for increasing the thoracic cavity. For the same reason the anterior torsion, being in a contrary direction to the posterior, increases still more the obliquity of the rib with refer-

* Downwards. † Upwards.

ence to the spine. But the relation of these torsions to the spine are different: the posterior torsion is relative to the spine laterally, while the anterior torsion relates to the spine more in the antero-posterior direction: they both conspire to increase the obliquity of the rib in *one* given direction,—from above downwards.

The torsion of the 1st rib, we have noticed, is directed in a contrary direction to that of other ribs; and we have observed that the presence of torsion in general favours muscular traction: but the 1st rib is an exception to this; here the torsion exists only between its two chief articulating processes, — the head and the tubercle: in the other ribs the torsion is between the tubercle and the body of the bone. The posterior torsion of the 1st rib appears to be merely destined to afford the head a more complete attachment to the body of the one vertebra (the 1st dorsal) to which that rib is fixed. A posterior torsion, in this short rib, is not needed for muscular traction, because here the scaleni are placed in the most favourable position — nearly at an angle of 90° with reference to the body of the bone in question, while their other insertion into the cervical vertebræ facilitates the most extensive and favourable means for its mobility, independently of any favouring twist in the rib for that purpose.

(4) *Surfaces* (*special differences*). — The thorax being conical, or somewhat barrel-shaped, it follows that the surfaces of the ribs, like the hoops of a very spherical barrel, must gradually change their direction; thus the surfaces of the 1st rib are nearly *superior* and *inferior*, this bone forming the lid to the thorax, while the surfaces of the 6th or 7th rib are *external* and *internal*, and as we proceed downwards to the 10th, 11th, and 12th ribs, the surfaces are again slightly tending towards a *superior* and *inferior* position, so that the internal surfaces of the 1st and 12th ribs are directed somewhat towards each other. The body of the rib, or that part which covers the lung laterally, and the anterior and posterior extremities, have also their surfaces inclined in different directions. Thus, take a perfect rib, say the 7th, laterally to the thorax the two surfaces are internal and external, while at the anterior end they are directed — external surface, forwards and downwards; internal surface, upwards and backwards; — at the posterior end, — external surface, upwards and backwards; internal surface, downwards and forwards. This is produced by their respective torsions. In some of the lower animals the ribs overlap each other like the tiles of a house; this sometimes threatens in man, particularly in diseases of the spine (*fig.* 666.), when they closely approach each other.

(5) *Specific differences of the extremities of the ribs*. — The greatest difference is in the posterior end of the rib. The anterior presenting little difference.

(a) *Anterior extremity*. — These are all hollowed out for their cartilage. As the ribs become more perfectly developed, for instance, the 5th, 6th, 7th, and 8th, the anterior extremity is broader, but not more deeply hollowed out than some of the other ribs, which are less perfectly developed, as in the 2nd and 3rd, or 11th ribs. This extremity is most pointed in the 12th rib.

Fig. 666.

Relation of the ribs to the spine in angular curvature.

(b) *Posterior extremity*. — The posterior extremity of the rib is more complicated, and has certain named parts, as the head, neck, tubercle, and angle, all of which become modified as we pass from above downwards. Their differences may briefly be noticed.

1*st Of the head*. — On the head of the rib, articulating with the vertebræ, a surface or facet is formed. The 1st, the 11th, and the 12th ribs articulate each with the body of one vertebra, and therefore they have *one* articulating surface. All the rest articulate each with the bodies of two vertebræ, and they consequently have *two* such articulating surfaces as already described. The head of the 1st rib is relatively larger than that of the others. For the most part, as the ribs increase in size, the head likewise increases, so that in the best developed rib the head and its surfaces are most perfectly formed, degenerating again to the 12th rib.

2*nd Of the neck*. — The neck being that part of the rib between the articulation of the rib with the bodies of the vertebra, and that with the transverse process, and these points differing but little in their distance from each other in the dorsal vertebræ, it follows that the absolute length of the neck of the different ribs is nearly the same. The necks of the ribs differ in their thickness, accordingly as their respective ribs increase or diminish in size; therefore, in the middle set of ribs, the necks are the thickest and strongest. In the 11th and 12th ribs, the neck, according to our definition, does not exist.

3rd Of the tubercle. — As the tubercle articulates with transverse processes, those ribs which have no such articulation have no tubercle; this is the case in the 11th and 12th ribs. The tubercles are most prominent in the superior ribs, gradually degenerating, or becoming less apparent, down to the 10th, where it is almost rudimentary.

4th Of the angle. — In strict anatomical language, the 1st rib has no angle, but the tubercle is very prominent, and gives the bone a very angular appearance, likewise in the 2nd, 3rd, 11th, and 12th ribs the angle is almost imperceptible, whereas it is well marked in the 4th, 5th, 6th, 7th, 8th and 9th ribs.

(6) *Groove* (*specific differences*). — The groove is not perceptible in the 1st, 11th, and 12th ribs, but distinct in all the intervening ones.

The 1st rib has two depressions separated by a tuberosity. The anterior corresponds to the subclavian vein, and the posterior to the artery of the same name.

Costal cartilages. — The flexibility and elasticity of the ribs is partly owing to their structure, but more especially to the cartilages which prolong them in front. (*figs.* 661, 662.) There are twelve costal cartilages distinguished numerically, as 1st, 2nd, 3rd, &c.; they are separated from each other by intervals which are very considerable at the upper part of the thorax, but gradually diminish as we proceed downwards. It is not very uncommon to meet with thirteen cartilages on one side, and at other times there are only eleven. Sometimes two cartilages are joined, and so aticulate with the sides of the sternum; when there are thirteen cartilages, the supernumerary one generally exists between the 3rd and 4th ribs; it is thin, and as it were rudimentary; it does not form the continuation of any rib, and terminates insensibly in the muscles. The cartilages from the 1st to the 7th articulate immediately with the sternum; and hence the name of sternal given to ribs with which they are connected. Of the other five cartilages, the last two have no connection with that preceding them; and from this circumstance, the name *floating* has been given to the last two ribs.

General characters of the costal cartilages. — All the costal cartilages are flattened like the ribs, and precisely resemble in breadth and thickness the bones to which they are attached. The external end is received into a cavity hollowed out in the anterior extremity of the rib; their internal or sternal extremity, which is much narrower than the external, is angular and articulates with the corresponding angular surfaces of the sternum. (*fig.* 661.) Their anterior or cutaneous surfaces are slightly convex, and covered by the muscles of the anterior region of the trunk, to many of which they give attachment. Their posterior or mediastinal surfaces are slightly concave. Their superior and inferior edges bound the intercostal spaces, and give attachment to the intercostal muscles. "They are," says Cruveilhier, "altogether distinct from articular cartilages, and have a peculiar tendency to ossify, this process taking place partly on the surface, and partly from within outwards."

Differential characters of the costal cartilages. — The costal cartilages, like the ribs, increase in length, from the 1st to the 7th, and sometimes the 8th, which in this case articulates with the sternum; from this they diminish in length to the 12th rib When we recollect the conical shape of the thorax this difference is to be accounted for, and moreover, the osseous parts of the upper ribs terminate anteriorly in a line directed obliquely from above downwards and outwards. The sternum is only about half the length of the lateral pectoral space, so that only the first four or five cartilages could join this bone, did not the others turn upwards to reach its sides (*fig.* 661.), by joining the lower edge of the immediately superior cartilage. The first three cartilages alone, therefore, follow the same direction as the long rib to which they articulate.

The *first cartilage* differs from all the others by its shortness, its thickness, and breadth, and its tendency to ossify; it is often, but not always, continuous with the sternum.

The 2nd and 3rd costal cartilages cannot be distinguished from each other, but they differ from the rest in being joined to the sternum at right angles, in not being bent, and in being as broad at their sternal as at their costal extremities.

The 4th cartilage becomes bent upwards, after having followed the direction of the rib for a little way. (*fig.* 661. *e.*) The length and the curvature of the cartilages of the 5th, 6th, and 7th ribs progressively increase, and across their intercartilaginous spaces they frequently touch each other. Their inner ends become successively narrowed so as to correspond with the diminishing cavities on the edges of the sternum. The borders of the 5th, 6th, 7th, and 8th costal cartilages articulate together, and present for this purpose articular facets supported by eminences. The cartilages of the 8th, 9th, and 10th ribs gradually diminish in length. Externally they have the same breadth as the rib, and decrease as they pass inwards, so as to terminate by a pointed extremity, which is applied to the lower edge of the cartilage above. The cartilages of the 11th and 12th ribs are extremely short, particularly that of the 12th, which is only a mere tip to the bone, and seldom exceeds four or five lines in length; their free extremity loses itself, so to speak, in the substance of the abdominal parietes; so that they are altogether unconnected with the other cartilages.

Liability of the costal cartilages to ossify. — The 1st cartilage usually becomes more or less ossified in adult age, and is often anchylosed to the sternum. After the middle period of life, osseous matter is likewise deposited to a greater or less extent in the other cartilages, and it is apparent in those of the false, later than in those of the true ribs.

These observations apply to the male body; for in the female the process of ossification does not affect the cartilages until old age has arrived, and it always affects a comparatively small number of cartilages, even if it should happen to extend beyond the 1st, which commonly is not the case.

Of the ligaments of the ribs. — The ligaments of the ribs may be divided into three sets, those which connect them, 1st, with the bodies of the vertebræ; 2ndly, with the transverse processes, and 3rdly, with the sternum. The rib is connected with the bodies of two vertebræ (excepting those specified above) forming with each a joint lined with synovial membrane, and held in place by the following ligaments: —

1st. With the bodies of the vertebræ. — *Costo-vertebral ligaments, (lig. capitulorum costarum).* — These consist, 1st, of an anterior ligament which connects the head of each rib with the sides of the bodies of the vertebræ. Its fibres, flat and radiated, are divided into three bundles, of which the middle one passes horizontally forwards upon the corresponding inter-vertebral cartilage, whilst the superior ascends to the body of the vertebra above it, and the inferior descends to that below. From the divergence of its fibres this is usually called the *stellate ligament.* 2ndly, of an *inter-articular ligament*, a thin and short band of fibres which passes transversely from the ridge separating the two articular surfaces on the head of the rib, to the inter-vertebral substance, and divides the articulation into two parts, each lined by a separate synovial membrane. This ligament does not exist in the articulation of the 1st, 11th, and 12th ribs, and in consequence there is in them but one synovial membrane.

2ndly. With the transverse processes of two vertebræ. — The rib at its tubercle forms a joint, lined by synovial membrane, with one transverse process; and to another (being separated from it by a considerable interval), it is connected by ligamentous structure of some length. The *costo-transverse ligaments* connect the tubercle and neck of the rib with the transverse processes of the vertebræ; they are named from their position, posterior, middle, and anterior.

a. The *posterior costo-transverse ligament* — (*lig. transversum externum costarum*, Weitbr.) consists of a very short, thick fasciculus of fibres, which passes from the posterior surface of the summit of the transverse process, to the rough, inarticular part of the tubercle of the rib. Those of the superior rib ascend, those of the inferior rib somewhat descend.

b. The *middle*, or *interosseous costo-transverse ligament* — consists of a series of very *short* parallel fibres, which unite the neck of the rib to the anterio surface of the contiguous transverse process. These fibres are best seen by removing horizontally a portion of the rib and transverse process, and forcibly drawing one from the other.

c. The *anterior*, or *long costo-transverse ligament* — (*lig. transversum internum seu cervicis costæ internum*, Weitbr.), is usually divided into two fasciculi of fibres nearly opposite to one another, and on the same plane. They pass from the neck of the rib obliquely upwards and outwards to the lower, margin of the transverse process next above it.

Characters peculiar to certain costo-vertebral articulations. — The articulations of the 1st, 11th, and 12th ribs alone present peculiarities.

a. Costo-vertebral articulation of the 1st rib. — The rounded head of the 1st rib is received into a cavity on the side of the body of the 1st dorsal vertebra, the articulation is therefore a species of enarthrosis; there is neither a costo-vertebral interosseous ligament, nor a superior costo-transverse ligament; the synovial membrane is much looser than in the corresponding articulations of other ribs.

b. Costo-vertebral articulation of the 11th and 12th ribs. — These present the same characters as the preceding, in this respect, that the anterior cavity for the head of the bone is situated upon a single vertebra. The head of the rib, however, is flattened, or very slightly convex. There is no interosseous costo-vertebral ligament. The superior costo-transverse ligament is much broader and stronger than in the other articulations. As the 11th and 12th ribs have no tubercles, and the transverse processes of the corresponding vertebræ are but little developed, it follows that there is no costo-transverse articulation: but yet there is a costo-transverse interosseous ligament. All these ligaments are much more loose than in the other articulations.

3rdly. With the sternum (*Chondro-sternal articulation*). — The costo-sternal articulation is between the angular extremities of the cartilages of the ribs and the corresponding fossæ in the margins of the sternum; these articulations are covered and supported by two sets of ligaments. 1st, by an anterior set of ligamentous fibres, thin, scattered, and radiated (*ligamenta radiatim disjecta* Weitbr.), passing from the extremity of the cartilage to the anterior surface of the sternum, where they interlace with those of the opposite side, and are blended with the aponeurosis of the pectoralis major muscle. 2ndly, by a posterior set of fibres similarly disposed, but not so thick or numerous, connecting the thoracic surfaces of the same parts; together with some ligamentous fibres placed above, and others below the joint.

A synovial membrane is interposed between the ends of each true rib, and the sternum. These membranes can be demonstrated by slicing off a little of the anterior surface of the sternum and cartilages. Cruveilhier doubts the existence of such synovial membranes; we are inclined to differ from him in this respect.

Characters peculiar to chondro- or costo-sternal articulations. — The 1st, 2nd, 6th, and 7th chondro-sternal articulations present the following peculiarities: —

1st, The cartilage of the 1st rib is sometimes continuous with the sternum, and is sometimes articulated like the cartilages of the other ribs. Cruveilhier found in one subject the 1st rib excessively moveable, because its cartilage, instead of being continuous with the sternum, had its upper edge applied to the side of that bone to which it was united by ligaments, and was ultimately articulated by a narrow extremity immediately above the 2nd rib.

2ndly. The second cartilage is much more angular at its inner extremity than any of the others : it is received into the retreating angle formed by the union of the first two pieces of the sternum. Sometimes there is an interosseous ligament in this joint, running from the angle of the cartilage to the bottom of the cavity, and there are then two synovial capsules; in other cases there is only one, but it is always more marked than in the other joints.

The articulations of the 6th and 7th cartilages, besides the anterior ligaments, have also a *chondro- or costo-xiphoid ligament*, more or less strong, which crosses with the ligament of the opposite side in front of the ensiform cartilage, and the lower end of the sternum. Sometimes this ligament only exists for the 7th cartilage ; it is intended not only to strengthen the chondro-sternal articulation, but also to maintain the xiphoid appendix in its place.

Connection of the ribs with their cartilages. — The cartilages are almost immoveably united to the ribs, being received into rounded depressions on the ends of the ribs, and their union is maintained only by periosteum, which may be considered to represent their ligaments.

Articulations of the costal cartilages one with the other. — Some of the costal cartilages articulate with each other by their edges.

The 1st, 2nd, 3rd, 4th, and 5th costal cartilages do not articulate together, unless the aponeurotic lamellæ, sometimes very strong, which form the continuation of the external intercostal muscles, and occupy the whole length of the cartilages, be considered as uniting media.

The 6th, 7th, and 8th cartilages, frequently the 5th, and sometimes the 9th, present true articulations with one another. Cartilaginous processes arise from the neighbouring edges and come in contact with each other : there are sometimes two articular faces between the 6th and 7th cartilages. The means of union are some vertical fibres united in bundles, so as to form two ligaments, the one anterior and thicker, the other posterior and thinner. The edges of the articulating surfaces, from the 6th to the 8th or 9th, are lined by synovial membrane. The 7th, 8th, and 10th cartilages have not always articular surfaces, but are simply united by vertical ligaments.

Ligaments of the sternum (*Membranæ sterni*, Weitbr.). — The pieces of the sternum are connected by a layer of fibro-cartilage, placed between their contiguous borders ; and, on the anterior and posterior surfaces, ligamentous fibres may be observed running longitudinally, which serve to strengthen their connection. They are sometimes called the anterior and posterior sternal ligaments. The longitudinal fibres are mixed with those radiating from the costal cartilages, especially in front of the sternum, where likewise they blend with the aponeurosis of the pectoral muscles. The anterior portion has thus most of the accessory fibres, and is rough and irregular ; the posterior one is smooth and pearly in its aspect.

The *muscles* of the thorax will be more conveniently noticed hereafter.

Of the Thorax in general. — The sternum, the ribs and their cartilages, together with the dorsal vertebræ, are so united together as to compose the frame-work of the thorax. (*fig.* 662.) Their arrangement is such as collectively to admit of great mobility, and at the same time to protect completely the organs of respiration and the heart. How well adapted this mechanism is for protecting those vital organs is well shown by the impunity with which the prize-fighter receives for many hours the trained blows of his antagonist.

Although the range of motion between each vertebra and the ribs attached to it, is very limited, yet the whole frame-work of the chest enjoys such mobility, that, by a deep inspiration, its capacity is sometimes more than doubled. This bony frame-work is by no means destined solely to cover the respiratory organs, for it extends considerably downwards, composing part of the abdominal walls within which lie the liver, spleen, kidneys, stomach, duodenum, and part of the colon ; hence the distinction between thoracic and diaphragmatic ribs. In fact it will be found that about one half only of the costal surface is destined to compose the thorax. The shade running transversely across the ribs in *fig.* 632. marks the bottom of the thoracic cavity.

In each individual the thoracic cavity corresponds exactly with the volume of the heart and lungs. But there is no relation between the volume of the lungs and the vigour of the constitution — nor between the size of the cavity of the thorax and the amount of air which can be respired, as will be hereafter shown. There is likewise no relation between the volume of the thorax and that of the abdominal cavity. No doubt the vigour of aëration in the lungs is at all times exactly commensurate with the vigour of the alimentary canal, so that the one harmonises with the other; but this *vigour* bears no relation to space or *size*. A small thorax may in some individuals admit of the inspiration of a greater volume of air than a larger thorax in others. In fact it may be commonly noticed that where there is a large abdomen there is generally a small thorax, and that the volume of air which can be expelled at one effort from the lungs of those who have a large abdomen, is less than from those with a small abdomen. The alimentary canal receives at once a given quantity of food, and there it remains for an indefinite time, the thorax large or small, it matters not which, aërates the blood from this food by movements, quick or slow, long or short; therefore the respiratory *movements* only, need be relative to the abdominal cavity, in the same way as the volume of the blast from a pair of bellows is more dependent on their mobility than on their absolute size. The above remarks are applicable to the thorax of either male or female.

I. *Boundaries of the thoracic cavity.*— The thoracic cavity, situated between the shoulders and below the neck, extends but a short way downwards, in the male about seven inches, and in the female about eight inches, below the clavicle, so that a horizontal line drawn about an inch below the axilla, corresponds (roughly) with its floor. The floor of the chest, therefore, is much higher up in the trunk of the body than is commonly supposed. The thorax is bounded anteriorly by the sternum and costal cartilages; laterally by the bodies of the ribs and the intercostal muscles; posteriorly by the vertebræ and angles of the ribs, and inferiorly by a thin tendinous and fleshy floor— the diaphragm. The *surior aperture* of the chest is about sixteen inches in circumference, this is the smaller end, and thence called the apex of the thorax. It is bounded *laterally* by the two 1st ribs, *anteriorly* by the upper edge of the sternum and inter-articular ligament, and *posteriorly* by the last cervical and first dorsal vertebræ. The *inferior aperture* is about thirty or thirty-one inches in circumference, and forms the base of the chest. Anatomists describe this part as bounded in front by the cartilaginous extremity of the sternum or xiphoid cartilage, and the cartilaginous extremities of the last true and false ribs, and more laterally by the 11th and 12th ribs, posteriorly by the last dorsal and first lumbar vertebræ. But as they assume to themselves the privilege of giving a bone a surgical neck as well as an anatomical one, so may we take a similar liberty in describing the thorax for medical purposes. In the examination of the chest during life, too exclusive attention to anatomical boundary has probably led to the error, of regarding the chest as much deeper than it really is, and thence to examining for disease of the lung where really little or no lung exists. A sharp instrument, piercing the chest laterally, at the cartilaginous extremities of the last true ribs, would most probably penetrate *no lung*, for the liver, spleen, stomach, &c. are contained within these points. The bottom of the chest is so moveable and so much arched (*See art.* DIAPHRAGM, *fig.* 3.), that in the different stages of inspiration, the lung assumes different positions This may be demonstrated by percussing over the 5th rib at its junction with its cartilage, first after a deep expiration and then after a deep inspiration; in the latter the sound is "clear," in the former it is strikingly "dull." Therefore, instead of taking the insertion of the diaphragm as the bottom of the thorax, it will be found more convenient for examining the chest to take the top of the arch of this muscle as the lower thoracic boundary, or the shaded line crossing the ribs in *fig.* 4., for the *medical base.* This may be described as corresponding in front with the xiphoid cartilage; laterally to different *osseous portions* of the 7th, 8th, 9th, 10th, 11th, and sometimes the 12th rib (*fig.* 682.), and posteriorly to the 8th and 9th dorsal vertebræ. This will place the bottom of the thorax in a very different position from what is generally supposed; for, if we express the distance from the 1st rib, to the lowest point of the 10th rib as 13·5, that from the 1st rib to the arch of the diaphragm or medical boundary will be only 6·25, less than one half the depth of the thorax as anatomically described. The medical base of the thorax forms a nearly horizontal plane, which extends between the sternum and the bodies of the 9th or 10th dorsal vertebræ, its posterior being somewhat higher than its anterior. But on each side of the bodies of the vertebræ there is a deep groove formed by the angles of the ribs. In that part of this groove which extends below the above-mentioned inclined plane, a wedge-shaped process of lung is lodged, which varies in size in different subjects, and consequently will be found to terminate at different points in the dorsal region, as already noticed, sometimes hanging down like a broad, thick flap, and at other times forming only an insignificant process.

In examining the chest, it is of paramount importance that the student should familiarly know this *medical floor* of the thorax. The sign laid down by the late Dr. Edwyn Harrison, for marking this boundary, we have found strictly correct in every normal-shaped thorax. Namely, take the xiphoid cartilage as a point to start from, and pass the *flat* hand horizontally from thence to the side of the chest, the index finger, when *horizontal,* will distinguish a slight depression or sulcus at the maximum lateral bulge of the thorax, then from this point slide the hand slightly upwards (perpendicularly), and it will pass over a bulge, about enough to fill the palm of the hand, into another sulcus, better defined than the former one; this groove corresponds with the medical base of the thorax, and a probe passed in here would graze the arch of the diaphragm after passing through the moveable inferior edges of the lungs. It is necessary that the hand be kept perfectly horizontal, or it will fall into an intercostal space, which does not correspond with the groove in question. With practice, the hand falls at once into the upper sulcus, without first searching for the lower one; indeed, latterly, Dr. Harrison allowed that the lower sulcus might be absent, and yet the upper one present.

This groove is higher upon the right side than upon the left, corresponding to the height of the liver.

By external observation, the medical base of the thorax may be known by the slight rotatory motion made upon the diaphragm when a person is walking. A kind of great ball and socket-joint may be conceived to exist between the abdomen and thorax, and the outer garments even exhibit a correspondence to this base of the thorax.

II. *Contents of the thorax.* — Not only does the thorax contain organs proper to itself, but it lodges and protects others passing to the abdomen; thus, the food we eat passes through the thorax to enter the stomach, while the eighth nerve both supplies the lungs and then passes onwards to the stomach. Like other cavities, the thorax is lined with a serous membrane (*pleura costalis*), which likewise invests the lungs (*pleura pulmonalis*) (See PLEURA). The heart and its blood-vessels, the trachea, and the lungs, almost completely fill the thorax. The remaining organs, viz., the origin of the sterno-hyoid and -thyroid muscles, remains of the thymus gland, lymphatic glands, mammary vessels, triangulares sterni muscles, the phrenic, the eighth pair, and the splanchnic nerves, the œsophagus, thoracic duct, vena azygos, and venæ cavæ, occupy very little space.

Thus the thorax is completely filled. The older anatomists, however, even as late as Benj. Hoadley's time, considered that there was a considerable space containing air, between the lungs and the walls of the thorax. Now, we know that any considerable accumulation of air in this situation would be destructive to the respiratory function.

III. *Shape of the thorax.*—The shape of the thorax is subject to many varieties which may be conveniently studied under the following headings:

External thorax. — The thorax in the perfect subject is somewhat conical, broader above than it is below; but when deprived of the upper extremities and their appendages, the contrary obtains, for it is narrower above than it is below (see *figs.* 662. and 630. *et seq.*). Therefore the notion we commonly connect with broad shoulders or broad back, has but a feeble relation with the absolute breadth of the thorax. In fact the diameter of the neck corresponds more correctly with the diameter of the upper part or true apex of the thorax. Freeman the American giant measured 26 inches from tip to tip of his shoulders, while the diameter at the lower part of his neck, in the same direction, was only 6 inches. In women the mammæ materially add to the dimensions of the chest towards the apex. We have found the measure of a female round the thorax over the mammæ 45¼ inches, while the root of the neck was 15 inches. Allowing two inches for muscle, &c., the true thoracic apex would not exceed 13 inches, whilst 45¼ inches was the apparent circumference of the thorax. The true apex of the thorax is loaded with large muscles, sometimes a vast quantity of fat, the upper extremities, and in the female with large mammæ besides. The true base of the chest is comparatively little covered, particularly below the axilla, where the serrati are seen. This is the weakest and thinnest part of the thorax, but it is well protected by the arms.

(a) *The anterior or sternal region of the thorax.*—In a well-developed thorax the sternum appears to lie in a fossa formed by the pectorales and mammæ. This region assumes more or less of the perpendicular, according to the carriage of the person; a perpendicular drawn to the external plane of the sternum would, however, be directed upwards. Laterally to this, the costal cartilages articulate with the sternum; and, still more laterally, the ribs and their cartilages unite, forming an oblique ridge from above downwards. (See *figs.* 680. and 681. the line on each side of the sternum.) Still more externally, and parallel to this, may be noticed the projections formed by the anterior angles of the ribs, which bound the anterior region.

(b) *The posterior or vertebral region.* — In the well-developed thorax the spines of the dorsal vertebræ lie in a deep groove formed by the great mass of the erector spinæ on either side. These masses extend outwards to about the posterior angles of the ribs, which are nearly in a plane with the spinous processes of the vertebræ, and may be easily distinguished, bounding the posterior region.

(c) *The lateral or costal region* is composed of the bodies of the ribs and the intercostal spaces. Much difference has prevailed amongst writers upon various points connected with the ribs, and the spaces between the ribs. Probably this may have arisen from their having made their observations upon the dead subject, wherein the ribs have collapsed to their minimum, or the thorax of a thin subject with the ribs expanded by, perhaps, 200 cubic inches of air, or the ribs when artificially articulated in the clean skeleton, wherein they are generally arranged too wide apart and too horizontal.

In the collapsed state of the ribs, *i. e.* after the most ample expiration by death, we notice

1st, That the intercostal spaces are *not* of a uniform width from the vertebræ to the sternum. They are most narrow behind, and become wider as they approach the sternum (*fig.* 680.). The 1st, 2d, and 3rd spaces upon the whole are broader than the five next inferior, and the 10th and 11th spaces are the widest (*fig.* 682.).

2dly, Their length differs with the length of the ribs; thus the two first and two last spaces are the shortest.

3dly, The position of the intercostal spaces is very oblique (*fig.* 684.), roughly speaking, about mid-way between the horizontal and the perpendicular.

4thly, They are moveable, and in the different stages of respiration they can assume different positions and different perpendicular widths.

It has been found necessary for the convenience of auscultation, to subdivide the thorax more minutely. The subdivision proposed by Laennec has been generally adopted, although some of the terms, like those of the respiratory sounds, have been modified by writers of later date.

The anterior and lateral superior division,

Table C. — Thoracic Regions.

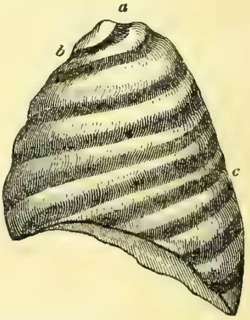
REGION.	SITUATION.
Anterior:	
Clavicular (subclavian of Laennec) - -	Portion covered by the clavicle.
Infra-clavian (anterior superior of Laennec)	Between the clavicle and 4th rib inclusive.
Mammary - - - - - -	Between the 4th and 8th ribs.
Infra-mammary (sub-mammary of Laennec)	From the 8th rib to the cartilaginous border of false ribs.
Sternal — superior, middle, inferior - -	Over the respective parts of the sternum.
Lateral:	
Axillary - - - - - -	All the axilla to the 4th rib inclusive.
Infra-axillary (lateral of Laennec) - -	Between the 4th and 8th ribs at the side.
Inferior-lateral - - - - -	Below the 8th to the false ribs inclusive.
Acromial - - - - - -	Between the clavicle, neck of humerus, and along the upper margin of scapula, including the root of the neck.
Posterior:	
Scapular, upper and lower - - -	Supra-spinous fossa and infra-spinous fossa.
Interscapular - - - - - -	Between the inner margin of scapulæ.
Infra-scapular (inferior dorsal of Laennec)	Below inferior angle of scapula and border of serrati to the level of 12th vertebra.

give the clearest sound upon percussion, and the back the least clear. Below Harrison's line, there is little or no evidence, from percussion, of the presence of lung, except in deep inspiration, and then the sound on percussion is mixed with other sounds from the abdominal organs. Only a small part of the mammary region covers lung, scarcely any being subjacent to the anterior parts of the 6th, 7th, and 8th ribs. (See *fig.* 4, wherein a transverse shading indicates the diaphragm.)

Internal conformation of the thorax. — To comprehend clearly the internal shape of the thorax, it is necessary to take a cast of this cavity. This may be done by making an opening in the sternal region, just large enough to admit the hand to remove the heart and lungs, filling up the whole of the cavity with plaster of Paris and returning the sternum, then opening the abdomen, cutting away the diaphragm, and so removing the cast, which gives us a clear knowledge of the internal conformation, and every kind of measurement correctly. (*Fig.* 667. is a cast from the cavity of *figs.* 680—685, — male subject.) We have stated that the perfect thorax viewed externally, and the same when the superficial muscles and upper extremities are removed, differ widely in their relative form. The thoracic *cavity* likewise differs remarkably from either of these views. The general view is that of a cone, but broader from side to side than from before backwards: therefore the cone is somewhat flattened.

(a) *Anterior region.* — This very closely resembles the anterior region of the external surface, being *convex* in its form, precisely corresponding with the concave sternum. The upper part, immediately behind the superior end of the sternum, is rather concave (*fig.* 667). At this part the cavity divides into two small cones, for the reception of the right and left apices of the lungs, which ascend upwards to a variable height, — an inch or an inch and a half. Both apices of the lungs are directed from below, upwards

Fig. 667.



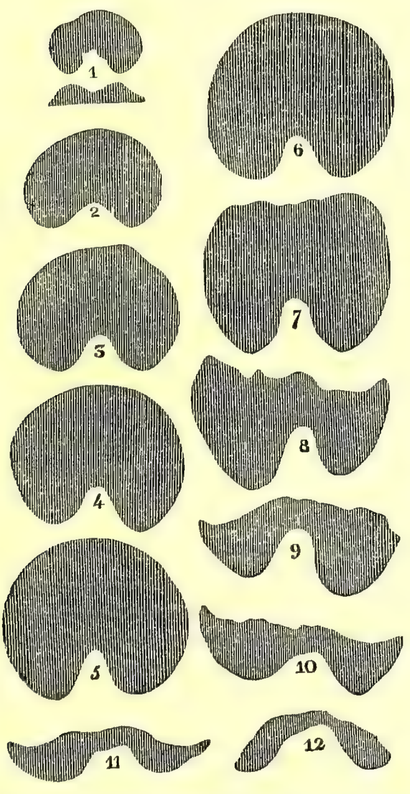
Cast of the cavity of the thorax represented in figs. 1, 2, 3, 4, 5, *and* 6.

and *forwards;* it is incorrect to consider them as directed backwards (*fig.* 667. *a*, which is the left apex seen above the 1st rib.) In some cases, particularly where the lung presents a puckered appearance, the axis of the apex is inclined nearly to the horizontal, and at all times it is about perpendicular to the sternum. These apices, throughout advancing life, are tending to incline forwards; it is this portion above the 1st rib (*fig.* 667.), which is so vulnerable in phthisis pulmonalis. There is great difference in the precise character of these apices in different individuals; in fact we have seen no two the same; some are remarkably truncated, and broad from before backwards; others are thin in this direction, and pointed; some obtuse and low, others acute and high. They have the same characters in both sexes. There is little difference in the height of the two apices. The elevation of the liver on the right side does not necessarily cause the right apex to be the higher. The right lung is more shallow than the left; but this is not because it is "pushed up," but because, in order to accommodate the liver, there is less *lung-substance* on the right side. If the mean of a series of observations represents the right side of the thoracic cavity as equal to 151, the left may be given as 182. The same may be said of both sexes.

(b) *Posterior region.* — If we examine this region upon a cast of the thoracic cavity, we observe in the middle line a deep fossa, formed by the projection, to the very centre of the thoracic cavity, of the bodies of the dorsal vertebræ.

This fossa is wider towards the base of the thorax, as may be seen by comparing the different sections of the cast (compare the notches, 10, 11, and 12, with those of 3, 4, and 5 in *fig.* 668.).

Fig. 668.



Sections of a cast of the thorax showing the space encompassed by each pair of ribs respectively.

The bodies of the thoracic vertebræ, form almost a complete septum; they are certainly a central column of support for the whole trunk of the body, bearing an equal distribution of the superincumbent weight in all directions. There is no part of the skeleton which more strikingly demonstrates that man was destined for the erect posture, than this central position, together with the increasing dimensions from above downwards, of the vertebral column. These conditions exist only in the human subject. The groove in the cast formed by the dorsal vertebræ is directed upwards and *forwards*, so that at the apex of the thoracic cavity it completely divides the lungs, producing two little cones laterally for the lungs, forming the right and left apex.

At the base of the thorax this perpendicular column again completely divides the lower lobes of the two lungs. The shape of the posterior part of the cast is that of a curve directed upwards, and sharply forwards, near the apex (*fig.* 667.). This curve near the apex is, like the form of the apices, very various.

An inflated lung assumes the same shape as this cast, giving even the marks of the ribs. The student, in order to have a correct idea of the lungs, should remove them from the body with the heart attached; then inflate them to their utmost, when their shape, their lobes, and relative mass before and behind, are clearly seen.

If now we inspect the cavity of the thorax itself, we find that the bodies of the vertebræ by their projection as above described, divide the posterior portion of the chest into two vast lateral grooves, which lodge the posterior portions of the lungs; these two grooves, partaking of the form of the thorax, are consequently conical in their configuration. They lodge fully one half of the entire lungs. This is worthy of remembering in reference to diagnosis, particularly when pneumonia is suspected; in such cases auscultation of the dorsal region demands as much attention as that of the anterior region. Though less vulnerable to phthisis pulmonalis, yet it may lodge disease in parts comparatively remote, and where inflammation may insidiously gain serious ground upon the patient, particularly in children.

(c) *Lateral region.* — This precisely corresponds with the external lateral view of the thorax (compare *fig.* 667. with *fig.* 680.); it presents indentation of the ribs, resembling a diagonal, curved, grate.

(d) *The base* of the thoracic cavity has been described above.

Conformation as affected by age and sex. — *Age* alters the conformation of the chest. In the earlier periods of existence the thorax is the smallest of the three great cavities, probably from the inactivity of the lungs. In the fœtal thorax the antero-posterior diameter exceeds the transverse diameter, the sternum projecting forwards, and the heart and thymus gland filling up the middle of the cavity. The ribs in fœtal life are less curved, and consequently those deep grooves, seen in the interior of the chest on each side the spine, formed by the angle of the ribs, so conspicuous in after life, are almost wanting; the vertical depth also is much less at this period, because the lungs are unexpanded and unemployed, while the abdominal viscera, particularly the large liver, are in activity and pushing up the diaphragm. The superior opening or true apex is greater from before backwards than transversely, which is the very contrary to the adult conformation. The inferior or true base of the thorax is extremely wide in every direction, from the encroachment of the abdominal viscera. At birth the thorax suddenly enlarges, by the air expanding the lungs to two or three times their previous cubic dimensions. As age increases, the curvatures of the ribs increase, and, with the vertebræ, running up through the very centre of the thorax, form the two great lateral grooves, peculiar to man, for lodging the chief bulk of the lungs. The depth of the thorax is diminished, while its breadth is increased, and this participates in that more perfect development of the system at the age of puberty. It is at this time that malformation of the chest frequently becomes obvious, particularly in females. In the adult age the thorax still grows, but in a degree less apparent, until it assumes the form of what is termed an open chest, capable of expanding in any direction, supplying us with air under violent exercise, and resisting severe blows. As age advances, through the decline of life, the thorax has a tendency to collapse ; the bony framework threatens to unite into one rigid cage, the true apex droops forward, the shoulders appear higher, and the round back of old age becomes apparent, so that we may make a tolerable guess at the age of an individual by the conformation of the back. The erect thorax is absolutely necessary to healthy vigour, while the drooping-forward chest is always accompanied with proportionate feebleness.

Sex. — The chief difference of external conformation between the sexes is due to the largeness of the mammæ, and the less width across the shoulders in women than in men. There is no distinguishing the sexes by the internal form of the thorax, they so perfectly resemble each other. The chest of the female is only absolutely smaller, but not always that, certainly not relatively so. The nipples are not uniformly in the same position ; those of the female are generally closer together than those of the male.

Conformation of the thorax affected by disease and occupation. — The conformation of the thorax chiefly depends upon the healthy condition of the main pillar of support, the spine ; but not always so, for that deformity called "chicken breast" appears to be independent of the condition of the spine. And, again, emphysema of the lungs tends to protrude the ribs and advance the sternum.

Disease, as caries of the vertebræ, or an atonic condition of the thoracic muscles, owing to which the spinal column may yield, either laterally, producing "lateral curvature," or anteriorly, giving "angular curvature," produces the most marked distortion of this pillar of support, and consequently of the whole thorax. In youth, particularly in females, (from the present system of education,) the spinal column, which is at all times sufficiently flexible, bends under the weight of the head and arms ; and for want of proper exercise the muscles of the back become enfeebled, and unable to restore it to the erect position. When "rickets" attack the spine, it may curve in any direction, compressing the ribs and projecting the sternum. It is surprising to witness to what an extent of deformity the thorax may attain, and yet life still remain (see *fig.* 666., where costal respiration could not exist ; and where all the abdominal viscera must have been forced up into the cavity of the thorax, for the 10th rib is nearly touching the crista of the ilium). We have noticed a case where such was the effort of nature to preserve the thoracic and spinal cavities, that life was maintained in a boy 14 years of age, though 7 bodies of dorsal vertebræ were completely absorbed.

In emphysema of the lungs, the sternum is protruded, and the antero-posterior diameter of the thorax is increased sometimes by an inch, the shoulders are raised, and the person assumes always the form of a man who has made the deepest inspiration.

In phthisis pulmonalis, the thorax changes its form, which is manifested by the shoulders inclining forwards, the anterior and superior parts bending in the same direction; the otherwise round full apex becomes flattened, collapsing upon itself; and there is an incapacity to extend the apex ; this is a sure and delicate test of that disease threatening, before any symptoms can be detected by auscultation. In other stages there is a loss of symmetry in the sides. In pleuritic effusion or in empyema, one side may be full and immovable, whilst the other has to perform the respiratory functions. In fact, disease of the respiratory organs may produce a change in the form of the thorax, either downwards, upwards, or outwards, or by collapse of the apex.

Frequently repeated or permanent compression, may produce many varieties of conformation of the thorax. Cruveilhier observes that infants, in whom the thorax was perfectly well formed at birth, have become deformed and flattened on the sides of the thorax, *by pressure from the hands of the nurse.* Slight external pressure in early life may be productive of permanent deformity of the thorax. The effect of strong and permanent constriction, as from tight stays, occasions a distortion in the form of the chest. This kind of compression principally affects the lower part of the thorax ; so that the 5th, 6th, 7th, 8th, 9th, and 10th ribs are pressed forwards and inwards, because the length of their cartilages allow them to yield readily : and the viscera corresponding to these ribs, also undergo alteration in their position and figure, encroaching upon the thoracic cavity, compressing the lungs upwards, into the apices of the chest. The imprudent custom of females wearing a hard unyielding piece of wood, steel, or whalebone up the front of their corset, commonly produces a compression inwards of the sternum. We once noticed a case where the sternum was forced inwards to such an extent, that the entire depth of the thorax, by *external* measurement, from the middle of the sternum to the corresponding part of the back, only measured 2 inches instead of 8 or 9 inches!

Occupation likewise modifies the form of the thorax. The clerk who writes many hours at the desk, carries himself differently to the soldier. Coal-miners have stooping chests when they work in districts where the coal seam is thin, and the roof consequently low, as in the north of England. In fact, all trades or occupations which require stooping for many hours together, tend to injure and malform the chest.

Pigeon- or chicken-breast. — This is a malformation quite distinct from any of the above mentioned, always affecting the sternal region in particular. An explanation of this curious disease has attracted the attention of Mr. Shaw, to whom we are indebted for the following remarks.* He noticed the effects produced upon the thorax by violent efforts of breathing in a child with croup. If we watch, says Mr. Shaw, the motions of the thorax in a young patient who is in danger of suffocation from an obstruction in the wind-pipe, we shall perceive that at each inspiration, while the superior ribs and sternum are raised and protruded as in common costal breathing, the lower ribs are, at first, flattened, and then drawn inwards, so as to produce a deep indentation on both sides. The depression is greatest in the line of junction of the ribs with their cartilages; it is as if a band had been tied tightly round the waist, or resembles the indentation near the margin of the chest, often seen in women from tight lacing. The constriction lasts during *inspiration;* in expiration, the ribs by their elasticity flap out and recover their form. That the lower ribs should be drawn inwards in the act of inspiration, diminishing the area of the chest at a time when their natural motion should enlarge it, will be understood by considering the relative conditions of the thorax and the lungs in the laboured respiration which arises from obstruction in the wind-pipe. Under the sense of impending suffocation, the young patient instinctively struggles to enlarge the cavity of the chest to its greatest capacity; but, while that effort is making, the quantity of air that passes into the lungs is very small, because of the obstruction in the larynx or trachea: a portion of air may reach the air-cells at the apex where the bronchial tubes are short, but little or none penetrates so far as the base of the lungs; consequently the lungs are imperfectly dilated. If the child succeed in enlarging the area of the chest in proportion to its powerful efforts, while the lungs were at the same time but partially dilated, it would follow that a vacuum would be produced in the space between the parietes of the thorax and lungs. But owing to the great flexibility of the ribs near the lower margin of the thorax in childhood, the atmospheric pressure overcomes the action of the muscles, and thrusts in the sides so as to preserve the balance of the air within and that without: in common language, the walls of the chest on each side are "sucked" inwards, like the valve in a pair of bellows.

When we look at the general shape of the chest during the continuation of the constriction, we perceive at once a resemblance to the pigeon-breast deformity; there is in both the same protrusion of the sternum, and the same depression of the cartilages on each side.

The question therefore arises, can the deformity have a similar origin to the change in the figure of the chest which is caused by difficult respiration? Dupuytren wrote a memoir upon this form of distortion, and he has shown that difficult respiration and pigeon-breast deformity are frequently associated together, so that he has almost constantly found that patients who are pigeon-breasted have at the same time enlargement of the tonsils; but Dupuytren does not profess to explain why the two complaints should go together. Some years ago Mr. Shaw had under his care a little boy with greatly enlarged tonsils, which were very low down in the throat, owing, as it appeared, to their having got within the grasp of the constrictor muscles of the pharynx. He had constant dyspnœa, and occasional fits of suffocation, in one of which Mr. Shaw performed laryngotomy: on his admission into the hospital, and for several weeks afterwards, it was observed that he had the "pigeon-breast" form of chest; but after his tonsils were excised, and his breathing had been perfectly free for some time, the sternum subsided to its proper level, and the thorax recovered its natural shape. These facts prove that a connection, like cause and effect, exists between obstruction of the air passages and pigeon-breast deformity. It is not necessary that such impediments should be so great as to produce strongly marked symptoms of dyspnœa; for, while the distortion is being produced the child is growing,—both the size and shape of the chest are undergoing a natural change. Mr. Shaw justly considers it quite possible that a cause which may have very slight influence in changing the figure of the thorax, if operating only for a week or a month, will, if continued longer, disturb and modify the process of growth; so that after intervals of half-years or years, a decided effect will be exhibited in the form of the chest. It is not impossible that continued disease in the air passages of children, which may fail to attract much attention, or at least may not be thought capable of producing distortion, may nevertheless gradually and insidiously give rise to the permanent deformity of "pigeon-breast." Mr. Shaw particularly refers to enlargement of the tonsils, attended even with slight inconvenience; to enlargement of the lymphatic

* Deformity of the Chest from Dyspnœa, Oct. 1841. Lond. Med. Gaz. New Series, vol. i. 1842.

glands in the course of the trachea or bronchi; to pressure upon the trachea by the thymus gland, when later than natural in being absorbed, or when hypertrophied; and to morbid thickening of the mucous membrane of the larynx, or of the trachea and bronchi succeeding croup or cynanche pharyngea. We concur with these views upon this subject, the more so as we likewise have noticed the pigeon-breast in children where enlarged tonsils have been present. We must not imagine from this that, where there is dyspnœa, there we shall always find the deformity in question; for difficult breathing may be caused by other circumstances than those which disturb the counter-pressure of the atmosphere in the thorax.

IV. *Dimensions of the thorax.*—The measurement of the thorax may be considered externally and internally; and, what is most remarkable, the one class of measurements may not have any relation to the other class. Moreover, the external measurements bear a certain proportion to the whole frame, whilst the internal do not.

(a) *External measurements of the thorax.*—The external dimensions of the thorax differ much in different men; this is obvious to all. There is the broad-chested and the narrow-chested man. Mr. Brent has calculated, from an extensive number of observations, the following proportions, which we arrange thus:—

TABLE D.—Relation of the External Chest to the Height, measured over the Nipples.

Minimum chest: $\frac{1}{2}$ of the stature — $\frac{1}{61}$ of the stature = circumference of chest.
Medium chest: $\frac{1}{2}$ of the stature + $\frac{1}{15}$ of the stature = circumference of chest.
Maximum chest: $\frac{2}{3}$ of the stature = circumference of chest.

For example, let us suppose a height of 61 inches, as follows,—

Minimum chest: height 61 in., $\frac{1}{2}$ = 30·5 in. — $\frac{1}{61}$ = 29·5 in. circumference of chest.
Medium chest: height 61 in., $\frac{1}{2}$ = 30·5 in. + $\frac{1}{15}$ (= 4·07) = 34·57 in. circumference of chest.
Maximum chest: height 61 in., $\frac{2}{3}$ = 40·7 in. = circumference of chest.

Thus, by taking the most perfectly proportioned chests, either from living figures or from the classical athletæ of ancient sculptures, the following is the result.

TABLE E. — External Thoracic Dimensions, (in three classes according to weight) in relation to the height, obtained from calculation.

MALES: CIRCUMFERENCE OF THORAX.			
Height.	Minimum Weight.	Medium Weight.	Maximum Weight.
Ft. In.	Inches.	Inches.	Inches.
5 0	29$\frac{3}{4}$	34	37$\frac{1}{8}$
5 1	30$\frac{1}{4}$	34$\frac{3}{4}$	37$\frac{3}{4}$
5 2	30$\frac{3}{4}$	35$\frac{1}{4}$	38$\frac{3}{8}$
5 3	31$\frac{1}{4}$	35$\frac{7}{8}$	39
5 4	31$\frac{3}{4}$	36$\frac{3}{4}$	39$\frac{5}{8}$
5 5	32$\frac{1}{4}$	37	40$\frac{1}{4}$
5 6	32$\frac{3}{4}$	37$\frac{1}{2}$	40$\frac{7}{8}$
5 7	33$\frac{1}{4}$	38$\frac{1}{8}$	41$\frac{1}{2}$
5 8	33$\frac{3}{4}$	38$\frac{5}{8}$	42$\frac{1}{8}$
5 9	34$\frac{1}{4}$	39$\frac{1}{4}$	42$\frac{3}{4}$
5 10	34$\frac{5}{8}$	39$\frac{5}{8}$	43$\frac{1}{4}$
5 11	35$\frac{1}{4}$	40$\frac{1}{4}$	44
6 0	35$\frac{5}{8}$	40$\frac{3}{4}$	44$\frac{5}{8}$

From this the minimum chests increase on an average nearly $\frac{4}{8}$ (3·9), the medium chests rather more than $\frac{4}{8}$ (4·2), and the maximum $\frac{5}{8}$ of an inch for every increasing inch of *stature*. We have found from *observation*, upon 1276 cases of all various classes conjoined, a regular arithmetical progression of the thoracic circumference over the nipples in relation to weight.

By the total mean of our observations the chest increases exactly one inch for every 10 lbs. increase of weight, sinking the effect of height, which, however, cannot well be omitted, because, as a general rule, the height increases with the weight.

Mr. Brent has found that twice the breadth of the shoulders equals the circumference of the thorax over the nipples — *i. e.* from point to point, or the caliber of the broadest part of the shoulders. Thus, if the caliber be 18 inches, the thorax will be 36 inches in circumference. Four times the distance between the nipples is equal to the circumference. Four times the antero-posterior diameter is equal to the circumference: therefore the distance between the nipples is equal to the depth from before backwards of the external thorax. At the height of 5 feet 9 inches this antero-posterior diameter varies from 7$\frac{1}{2}$ inch. to 12$\frac{1}{4}$ inches.

(b) *Internal measurement of the thoracic cavity.*—Before entering into details we may observe, that the thoracic cavity is much smaller than we might, perhaps, be led to expect; that the depth from above downwards is, when compared with the body, very shallow. It is, however, capable of enormous dilatation or mobility, even to 100 per cent; 80 per cent is common.

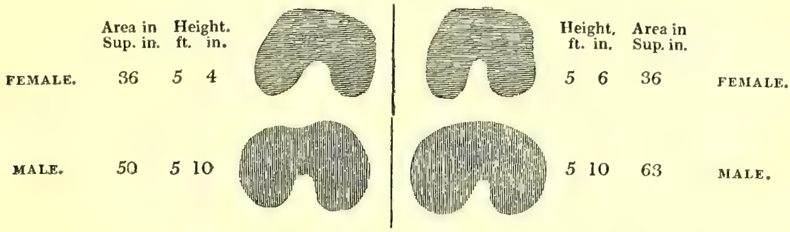
The *absolute* dimensions of the thoracic cavity of *females* are obviously smaller than those of males, because they are altogether of smaller conformation, both in stature and weight; but, *relatively*, the difference is probably little. Although the proportion of some of the diameters may differ, yet that of the total cubic measurements appears not to do so.

A certain rude relation of necessity must exist between the size of a man and the dimensions of his thoracic cavity. A man 7 feet high will have a larger chest than one 5 feet or 6 feet high. But there is no *constant* and uniform relation of the *size* of the chest, either to the height or weight of the body. The *function* of the chest, however, as indicated by the quantity of air which we can expel, is in strict relation to the minute difference of a single inch of stature, or to 10 lbs. of weight. It appears probable that the function of an organ may be exactly relative to the size of the body, increasing or decreasing with it, while the organ itself bears no visible relation of volume either to its own activity or to the dimensions of the body.

The greatest perpendicular depth of the thoracic cavity, nearly corresponds with the greatest lateral measurement; or if the depth be 8·7 the breadth is 9·7, and allowing for the mobility of the base of the thorax, the depth may yet more closely correspond to the breadth. The average perpendicular depth of the female thorax exactly corresponds with the average breadth, being 8·1 inches in both measurements. The greatest antero-posterior diameter in both sexes, *i. e.* from the sternum to the deepest part of the great lateral groove at the angle of the rib, is always less than the greatest lateral breadth, being as 6 to 9 in the male, and as 6 to 8 in the female.

These diameters, however, in no way correspond to the stature. A man, 5 feet 4 inches high, measured from the apex of the chest to the base $10\frac{1}{2}$ inches, whilst a man of 5 feet 10 inches, only measured $7\frac{1}{2}$ inches in the same direction, or the shorter man exceeded the taller by 3 inches in the perpendicular depth of his thoracic cavity:—but the taller man could exceed the shorter by a volume of 77 cubic inches of air at one deep expiration. In fact, the whole of the

Fig. 669.



Sections of the Chest at the base.

Table F. — Average Measurements of the Thorax.

(The mean of the measurements of fourteen males and six females, — given in detail in Med. Chirurg. Trans. 1846. Vol. 29. p. 176.)

	MALES.	FEMALES.
Age - - - - - - - - -	51 years	40 years
Height - - - - - - - - -	66 in.	62 in.
Weight (without clothes) - - - - - -	110 lbs.	94 lbs.
Weight of heart - - - - - - - -	13 oz.	11 oz.
Weight of right lung - - - - - - -	30 „	19 „
Weight of left lung - - - - - - - -	25 „	17 „
External circumference over nipples - - - - -	32 in.	30 in.
Internal circumference (maximum) - - - - -	32 „	24 „
Internal circumference of right half - - - - -	15 „	13 „
Internal circumference of left half - - - - -	15 „	13 „
Greatest depth, from before backwards, of thorax - - -	6·5 „	6 „
Distance between sternum and bodies of dorsal vertebræ - -	4 „	4 „
Projection of dorsal vertebræ into thoracic cavity - - -	2·5 „	2·5 „
Greatest breadth of cavity of thorax - - - - -	9 „	8 „
Internal superficies of costal walls of thorax - - - -	258 sq. in.	212 sq. in.
Superficies of diaphragm - - - - - - -	49 „	35 „
Superficies of entire boundaries (diaphragm and costal—) - -	307 „	247 „
Volume of right half of thorax - - - - - -	151 cub. in.	109 cub. in.
Volume of left half of thorax - - - - - -	182 „	141 „
Volume of entire cavity - - - - - - -	333 „	250 „
Depth of right lung from apex to arch of diaphragm - -	7 in.	7 in.
Depth of left lung from apex to arch of diaphragm - -	9 „	8 „
Depth from between apices to diaphragm - - - -	8 „	7 „
Depth from before backwards — right lung (maximum) - -	6 „	5·5 „
Depth from before backwards — left lung (maximum) - -	6·5 „	5·5 „
Distance between centre of apices of lung - - - -	2·5 „	2·3 „
Vital capacity - - - - - - - -	205 cub. in.	187 cub. in.

In the males the left apex was highest in 6, the right in 6, and in 2 the summits of the apices were on the same level; in the females, the left apex was highest in 2, and the right in 4.

internal measurements (cubic or diameter) clearly bear no relation to the height or weight of the man, whilst *vital capacity* * does so in an exact ratio.

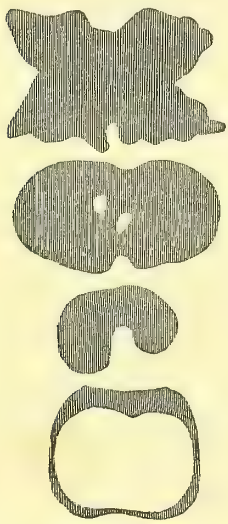
If we take a cast of the thoracic cavity and view the *base*, it presents the shape of the figures in diagram *fig*. 669. which gives a mean measurement, in the males of forty-six, and in females of thirty-five, superficial inches In the diagram (reduced by scale), we affix the height of each case, and the area in superficial inches of such section.

But the base of the thorax presents another measurement, that of the absolute area of the diaphragm. By the *figs*. 2. and 3., art. DIAPHRAGM, this muscle will be noticed as a large muscle of a vaulted form. C. *fig*. 670. represents a section of a thorax, the measurement of

Fig. 670.

Sup. Squ. in.

A 133



B 110

C 40

D 101 outside. 74 inside

Dimensions of the diaphragm in three stages.

C, ordinary stage. B, spread out A, completely extended. D, relative difference between expiration and inspiration.

which is forty superficial inches; the figure B, next above, is the diaphragm of the same person spread out, which is extended to 110 square inches, being nearly three times the area of the former figure ; even in this condition the centre is quite free, and not upon the stretch, though the circumference is so. The full measurement is nearly obtained, by slitting up the sides, as shown in figure A. and this condition gives it an increase of twenty-two superficial inches, making altogether 133 square inches ; but even in this condition the entire arched muscle is not perfectly spread out. This was the diaphragm of a man five feet six inches high, with an exceedingly small chest, only twenty-nine inches in external circumference, and whose vital capacity was 188 cubic inches. The section, therefore, of the thorax to the area of the diaphragm is as 40 to 133, or 1 to 3·3. This renders the base of the thorax highly mobile.

There is, perhaps invariably, a *difference in the dimensions of the two sides of the thorax*, in favour of the left side. The least difference which we observed was one cubic inch, but we think there must have been some error in this observation. Passing this over, we may say that the difference between the two sides varies from 10 to 77 cubic inches, and that, in all cases examined by us, the left side was larger than the right. This difference, also, we have found not to bear any relation to sex or stature. One female of 5 feet 4 inches in height had a difference of 77 cubic inches, which exceeds by 10 inches any of the males which we examined, up to 5 feet 10 inches high.

OF THE RESPIRATORY MUSCLES. — There are certain muscles *especially* destined to expand and contract the thoracic cavity, and there are others which act in different degrees as accessories, they may be classed as direct and indirect respiratory muscles.

The *direct* respiratory muscles are, *intercostales externi* and *interni*, *levatores costarum*, *infra costales*, *triangularis sterni*, and the *diaphragm*. The *indirect* respiratory muscles are all those which straighten the spine or aid in fixing the whole body for the thoracic muscles to act from as a fixed point, whilst by their other attachment they elevate or depress the ribs ; these are particularly the muscles of the neck and upper extremities, and those composing the walls of the abdomen. More indirectly still, the muscles of the limbs assist in respiration ; — in difficult respiration, the patient seizes hold of any fixed object, whilst he employs his whole muscular force to assist in inspiration, or, as Boerhaave has expressed it, " scarcely any particle remains in the body which is not more or less concerned in the business of respiration."* The indirect respiratory muscles, in fact, comprise nearly all the muscles of the body ; therefore we shall only notice the direct respiratory muscles. The diaphragm has already been described (art. DIAPHRAGM).

I. *The intercostal muscles* are arranged as two thin laminæ between the ribs ; one lamella is external to the other, hence they are named external and internal. The fibres of each layer are oblique in their direction in reference to the ribs, and each layer has its fibres disposed in a contrary direction to those of the other ; thus they are said to decussate. The twelve ribs form eleven intercostal spaces, consequently there are eleven such decussating lamellæ on each side of the thorax, and twenty-two in all. Their attachments are to the inferior border of one rib, and to the superior

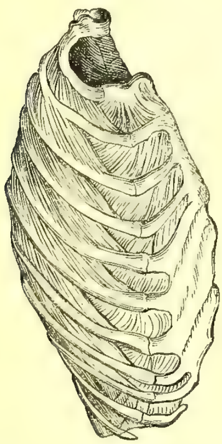
* By "vital capacity" is meant the measure of the mobility of the chest, as more fully explained hereafter. (P. 1056.)

* Prælect. ad Instit. 601. Morgagni. By Alexander, vol. i. p. 357.

border of the next below. They do not accompany each other throughout the entire intercostal space. These muscles, therefore, differ from each other in two ways, in the direction of their fibres, and in the extent of their attachment, for neither set are prolonged throughout the entire length of an intercostal space.

(a) *Intercostales externi.*—These have their fibres running obliquely downwards and *forwards;* they are continued throughout the whole osseous intercostal space, *i. e.* from the tubercles of the ribs, to where the cartilages commence; here they terminate. Haller once noticed these fibres "continued without interruption to the sternum, filling up the intercartilaginous spaces."* A thin aponeurosis is prolonged from the free anterior margin of this layer, up to the sternum. This muscular layer is thicker than the internal layer. *Fig.* 671. represents the anterior extremity of this

Fig. 671.



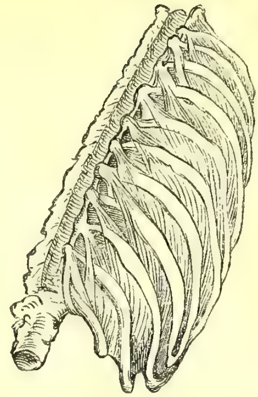
External intercostals. — Anterior view.

layer, where it terminates with the osseous part of the rib, and *fig.* 672. the posterior view, commencing at the vertebræ.

(b) *Intercostales interni.* — These, as their name implies, are internal to the above layer. Their fibres are likewise oblique, and have a contrary direction, downwards and *backwards* crossing the former layer. They commence at the sternum, fill up the intercartilaginous spaces, and *part* of the interosseous spaces, and terminate at the angles of the ribs. *Fig.* 671. represents them commencing at the sternum, and disappearing behind the external layer. *Figs.* 673. and 674. show them for the remainder of their course; in *fig.* 673. they will be seen to terminate short of the vertebral column. A thin aponeurosis is prolonged from their free margin backwards, to the end of the intercostal spaces.

All the intercostal fibres are oblique in their direction, with reference to the spine and sternum. The fibres of one intercostal space differ

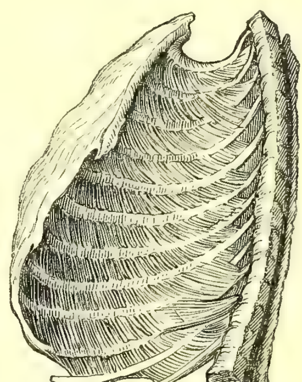
Fig. 672.



External intercostals. — Posterior view.

in their degree of obliquity relatively to those of other intercostal spaces Thus, broadly, it may

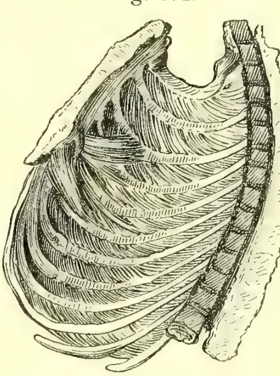
Fig. 673.



Internal intercostals. — Posterior view.

be stated that the external intercostal fibres *increase* in the degree of their obliquity as they

Fig. 674.



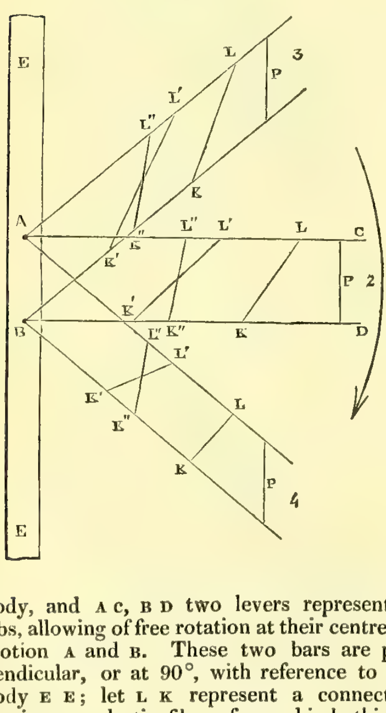
Internal intercostals. — Anterior view.

proceed from the first to the last intercostal space; and that the internal intercostal fibres,

* El. Phys. tom. iii. p. 29.

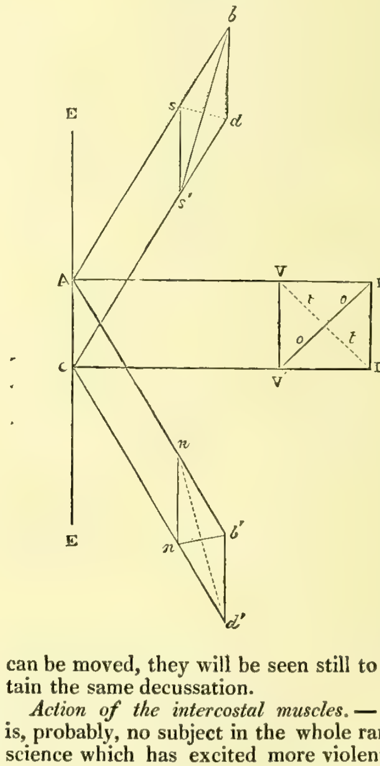
on the contrary, *decrease* in the degree of their obliquity as they proceed in the same direction. Moreover, for the most part the external fibres increase in their obliquity in the *same* intercostal space as you proceed from the vertebræ towards the sternum, and the internal intercostal fibres, on the contrary, increase their obliquity from the sternum towards the vertebræ, therefore they seldom decussate at right angles to each other, or form a perfect cross like the letter X. This is their general relative position at death, but, during life, in every stage of respiration, their degree of obliquity varies. The obliquity of the intercostal fibres should be viewed more with reference to the spine than to the ribs, because we shall show that their action is relative to the spine, and not to the ribs and that they may be perpendicular to two ribs, while they are oblique to the spine, because the ribs are themselves oblique. We have never seen any of the external intercostal fibres perpendicular to a rib, but we may see that arrangement in the internal layer of the lower intercostal spaces (*fig.* 673.). The omission of the relative position of the spine with reference to the obliquity of these muscles has led to many false conclusions as to their action in respiration. Let E E (*fig.* 675.) represent a spine or a rigid

Fig. 675.



body, and A C, B D two levers representing ribs, allowing of free rotation at their centres of motion A and B. These two bars are perpendicular, or at 90°, with reference to the body E E; let L K represent a connecting tension or elastic fibre of any kind, this is oblique with reference to the two bars A C and B D, but move these bars down to the position of P 4, at an angle of 45° to the body E E, and the fibre L K becomes perpendicular to the two bars; now move the bars up to P 3, also at an angle of 45° with E E, and the fibre L K becomes more oblique than at the position P 2. Therefore a tension may change from the *oblique* to the *perpendicular* relatively to the ribs; but it can never so change its relation to the spine. Thus L″ K″ and L′ K′ between the bars at P 3 cross each other, in the same *direction*, but in different *degrees of obliquity;* when the bars are at P 4., they decussate in directions contrary with reference to the bars, but not with reference to the body E E. The position of the ribs is similar to the bars at P 4, therefore the decussation of the intercostal muscles must be viewed with reference to the spine. The intercostal fibres never cross each other like the lines L′K′ and L″K″ (*fig.* 675.), nor can they, by any change of movement, ever assume thatposition ; *i. e.* if they do not decussate in a direction contrary with relation to the spine, in no change of position, throughout the range of a semicircle, can they ever become directly decussating fibres but when they directly cross each other as V D and V′ B (*fig.* 676.) relative to E E, in every other position to which the bars

Fig. 676.



can be moved, they will be seen still to maintain the same decussation.

Action of the intercostal muscles. — There is, probably, no subject in the whole range of science which has excited more violent contention and acrimonious dispute, than that of the action of the intercostal muscles. The illustrious and learned Haller could not enter this field of inquiry without pausing to observe: "Let it be allowed me to deplore among the miseries of human life, that such anger and bitter quarrels should be forced upon us on account of matters wherein we are so little personally concerned."*

Yet, strange to say, Haller opposed with extreme violence his contemporary Hamberger, whose investigations on this subject, though still extant, fell, consequently, into oblivion.

We know not who discovered the two sets of intercostals. There appears to be no account of them prior to Galen, A. D. 131. He observes, "the intercostal muscles help the midriff, that they might draw the chest inward."† Albinus (A. D. 1770) considered that both the internal and external layers "raise the ribs."‡ H. Cooke, a learned compiler of 1651, believed, they "constrained and dilated the chest," — "that the external layers bear down the ribs, and that the internal separate the ribs, so enlarging the thoracic cavity."§ Strange to say, after this Cooke divests these muscles of all thoracic motion whatever.

In 1685 it was the received opinion that the external layer dilated, and that the internal layer contracted the thorax.|| John Alphonso Borelli led the way to a different opinion, which prevailed amongst most physiological writers. He believed, from mathematical reasoning, that "the fibres crossing each other produced only one effect, viz., the drawing of the ribs together," — acting in the diagonal of the decussation. It is curious that he never considered the probability of the two forces acting separately, as other antagonising muscles can do.¶ W. Cheselden believed that both these muscles dilated the thorax, acting as elevators of the ribs, when the 1st rib was fixed by the scaleni and serratus posticus posterior.**

Cooke follows the views of Cheselden and Borelli.†† Benjamin Hoadly takes another view; and, in so doing, illustrates the subject with diagrams, and comes to the conclusion that the external layers elevate, and that the internal depress the ribs; and that their combined action is to arrest the respiratory movement at will. He also says, "*neither* range can by their action push the ribs asunder."‡‡ Winslow agrees with Borelli: presupposing, as usual, that the first rib is fixed.§§

Still the subject continued to be warmly disputed, when Haller published a controversial paper in 1746. In his "*Elements*," he treats the subject at length, siding with those whom he thinks are right, and confirming the same by many direct experiments.* Haller's view is, that the external layers *elevate* the ribs, because their superior attachment is nearer the vertebræ than their inferior one. Franciscus Boissier de Sauvages agrees with him; and the same is held by the majority, yet some doubt it.

His opinion touching the internal layer is, that they likewise act as associates and elevators of the ribs with the external layer, because "their superior attachment is nearer the sternum, and further from that bone in the lower ones;" likewise, that "that portion of the internal layer placed between the bony parts of the ribs, cannot have a different action from that portion placed between the cartilages." Joh. Swammerdam, Francis Bayle, J. Wilhelmus Pauli, Christianus Vater, Francis Nicholls, J. Fredericus Schreiber, differ from this, believing that the internal layers draw down the ribs.

Now follows a sharp antagonist to Haller, viz. Hamberger, whose disputes with Haller we gather from Haller's writings, and not from Hamberger's writings.

Hamberger breaks out with an entirely new view, which excites Haller to controversy.†

Hamberger, says Haller‡, believes that the external intercostal muscles have one action, — that they would raise the sternum: "that the internal layer would depress it." Hamberger makes a machine "to demonstrate, that when the ribs are raised by these muscles their intervals are *dilated*; when depressed, on the contrary, they are diminished." He furthermore gives, as his own discovery, that "the internal intercostals conjoining the osseous portions of the ribs, and that portion which is between the cartilages, will raise them, and are therefore associated in action with the external layer." Hamberger was the first to assign a double action to the same class of muscles: he likewise believed that the whole ribs were lifted simultaneously.§ Haller disputes the validity of Hamberger's experiments, upon the ground of his not considering the relative mobility of the first and second rib; because, says Haller, if the depressing power of the intercostal muscles is to the first rib as 20, the elevating power on the second rib, by reason of the difference of length and mobility, is as 380, nearly nineteen times greater; and the lower rib is to each superior rib, as far as the seventh, more moveable, in the ratio of 109 to 79.|| We cannot see, with Haller, how the ten-

* El. Phys. vol. iii. p. 36.

† De Usu Resp., ch. 15., 5 lib., De Usu Partium.

‡ Tr., fol., ed. 1777. Tab. xvii. 9, 10, et seq.

§ Cooke's Descrip. Anat., fol., 1651., p. 257.

|| Samuel Collins's System of Anat., fol., 1685, vol. ii. p. 825.

¶ De Motu Animalium, pars secunda. Lugduni Batavorum, 1710, p. 106., Prop. 84., Tab. xviii. Fig. 2.

** Anatomy of the Humane Body, 3rd ed. 8vo., Lond. 1726, p. 117.

†† Cook's Anat. and Mechanical Essays, Lond. 1730, vol. i. p. 282. et seq.

‡‡ Gulstonian Lect. on Resp. 4to., Lond. 1740, p. 6.

§§ Anatomical Exposition, 4to,. Lond. 1749, vol. i. p. 318.

* Vide Elementa Physiol. Corporis Humani, tom. iii., p. 28., et seq. Lausan. 4to., 1766.

† Hamberger was born 1697, and died in 1755. Haller's first anatomical paper upon respiration appeared in 1746, and his Elementa Physiol. Corporis Humani, in 1757-66.

‡ El. Phys. ib. p. 37.

§ Hamberger's writings on this subject were an essay De Respirationis Mechanismo, Jenæ, 1727, and also Physiologia Medica, Jenæ, 1751. — Ed.

|| Loc. cit. p. 39. et seq.

dency of action of a muscle can be affected by the degree of mobility of a joint; for it is not necessary to the *direction* of the action of a muscle that a bone should move. Haller also denies that the two crossing fibres lengthen and shorten inversely to each other; or that the intercostal spaces widen by their action. Haller performed many experiments; he applied strings to the ribs of a wet preparation, representing the muscles, and pulled the strings, and the intercostal spaces diminished. By vivisections he determined, that in inspiration the internal intercostals, "simultaneously with the external layer, contract, swell, and wrinkle, become perpendicular and hard, with united lifting of the ribs in rotation, the turning of the lower border forwards, the protrusion of the sternum, the descent of the diaphragm," &c. On the other hand, he observed in "expiration, relaxation of the whole series of intercostal muscles, increased length and obliquity, increased distance between the spaces, relaxation of the diaphragm, repression of the sternum, the descent of the ribs, narrowing of the chest," &c.*

It is curious to see that he makes the cubic space of the thorax diminish with the intercostal spaces *widening*. Nor do we wonder at his observing, in his vivisections, a contraction of both sets of these muscles, for he not only skinned his animals, but "cut down and destroyed the external layers of intercostals, to lay bare the internal layer.' "Besides I applied (says Haller) pain *and fear*, being more efficient than mere pain itself," by puncturing the diaphragm to cause dyspnœa! Under such circumstances — an animal tied down, divested of all superficial muscles, with a pierced chest, — in "pain and fear," — and writhing under the scalpel, — producing tetanic convulsions, and then a death-like relaxation from syncope, — surely in such a condition the action of the respiratory muscles, so sensitive to the least mental emotion, could not well be determined.

Although Haller appears *positive*, yet he concludes his controversy with a brilliant question,—a vivid picture of his master mind, — "Why has nature made two, rather than one set of intercostal muscles, if, indeed, the function of each is the same?" † Haller's views have, however, prevailed to this day, and are still taught in our schools. Some authors have assigned but little to these muscles, counting them as mere associate muscles; others, that they are "wholly and solely" to form the thoracic parietes; others that they are rather movers of the spine.

Dr. John Barclay, a standing authority, observes, that the supposition of the two sets being antagonists in their actionr "is now obsolete," and must "have been formed by the very witchcraft of imagination, in defiance of all observation and experiment." ‡

Lastly, Dr. Sibson has made a communication upon this subject. He observes, that "the scaleni invariably act during the whole time of inspiration;" and that the function of the intercostal muscles is complicated; thus, "the *external* intercostals, between the thoracic set of ribs, are throughout *inspiratory;* those portions between their cartilages are *expiratory*, between the diaphragmatic set of ribs they are *inspiratory behind*, *expiratory* to the side and in front, and between their cartilages they are *inspiratory;* between the intermediate set of ribs they are for the most part *slightly inspiratory* between the ribs, and *expiratory* in front between the cartilages."

"The *internal* intercostals of the thoracic ribs are *expiratory* behind and *inspiratory* in front, if the ribs approach there, and are *inspiratory* between the costal cartilages. Between the diaphragmatic and intermediate set of ribs, and between the cartilages, they are thought *expiratory*."* From this view of Dr. Sibson's, we venture to gather, that different fibres of the same layer of intercostal muscle have diametrically opposite actions. We do not understand upon what ground it can be demonstrated that one muscle having a given action between two ribs, shall, between the same ribs, and observing the same obliquity and same attachments, present a directly contrary action; the conditions are the same, and therefore the action must be the same. These views, however, of Dr. Sibson, in the paper in question, are not borne out by the narration of any experimental facts. Insufflation on the dead body is not the movement of inspiration in the living subject. It is better to assign to these muscles the terms of elevators or depressors of the ribs, instead of inspiratory and expiratory muscles.

All these observers, as far as we have seen, pre-suppose that the 1st rib is fixed by the scaleni (this is the view now taught); and that according to the fixing of the 1st rib, all the intercostal muscles are either elevators or depressors of the ribs. It is curious to contemplate that, out of elements so few, two ribs and two muscles, opinions so contrary should be held with regard to the action of these muscles. They have nevertheless an action as definite as any other muscle in the body.

We may here observe, that, although the chest is conical, the ribs segments of circles, and the spine mobile, yet treating them as planes and lines will not lead to error. Two parallel bars, rotating on a centre, will increase and decrease the perpendicular distance between them; so they will, if curved like the ribs. This we have determined by experiment.

Although the rib has two movements, elevation and rotation, yet these are associates, and do not obstruct each other. We shall employ the same diagrams as used by Dr. Barclay, when describing the same muscles.

The intercostal muscles act as a force between two moveable ribs or levers; therefore let us consider —

* El. Phys. ib. p. 43.

† Ib. p. 44.

‡ Barclay "On Muscular Motion," 8vo. Ed. 1808, pp. 533, 534.

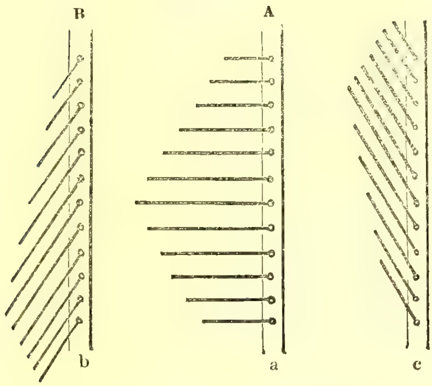
* Tr. Phil., Pt. 4, 1846, pp. 543, 544.

1st. The movement of such levers, when rotating.

2nd. The effect of forces, oblique, perpendicular, and decussating, upon such levers.

1st. *The movement of the levers.* — Let *fig.* 677. A represent a series of parallel bars,

Fig. 677.



allowing of free rotation upon a rigid perpendicular body A a; let the free extremities of these bars be kept apart, so that the bars may at all times be parallel to each other. In this condition a certain distance exists between the bars, and a certain distance between their free extremities and the perpendicular body A a. Let B represent the same bars moved into another position, resembling that of the ribs; in this position, the two conditions seen at A are altered. The perpendicular distances between the bars are diminished, and the distance between the free extremities of the bars and the body B b is likewise diminished. If the direction of this motion were still continued, the bars would ultimately touch each other, and their free extremities would be still nearer to the body B b. But let the bars be elevated, as in C c, and the same condition obtains as in the bars at B b, viz., they approximate each other, and the free ends come nearer to the body, C c. In this case the *bars only* have moved; but the same effect can be obtained without moving the bars. Let A B (*fig.* 678.) be two bars at their maximum distance, while horizontal; at *a b*, and *a′ b′*, they have nearly attained their minimum perpendicular distances, though still horizontal, because the rigid bodies *c c* and *c′ c′* have been moved respectively. Now, if we join these hree last figures into one, as in *fig.* 679., an then move the bars simultaneously, some bars will approximate each other, whilst others will recede. The superior four are at their maximum perpendicular distance from each other; while the 4th, 5th, and 6th are at a medium perpendicular distance, and the 6th, 7th, and 8th bars at their minimum distance.

The distances of these bars are regulated by the position of the rigid body representing the spine. If all of them were moved upwards

Fig. 678.

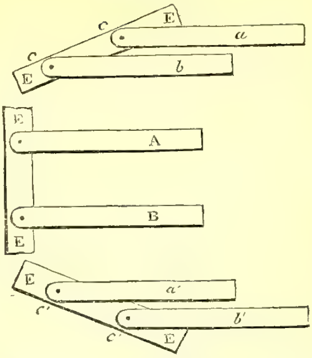


Diagram representing the position of the ribs affected by the position of the spine.

simultaneously, the first four would approximate, whilst all the rest would recede from each other. Therefore the positions of the different parts representing the spine in *fig.* 679. command and regulate these changes.

Fig. 679.

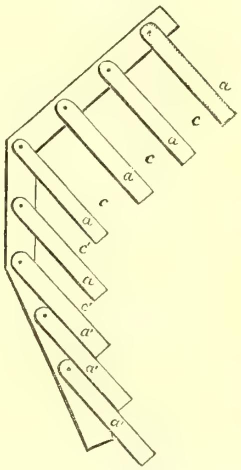


Diagram as in fig. 678. *with the three portions conjoined.*

From this we learn, that the bars cannot rotate without changing their distances, and that when they are at 90° with reference to the body A *a* (*fig.* 677.), they are at their maximum distance from each other, and as they pass this position on either side, this distance diminishes.

In the human body the spine may represent the body to which the bars are attached (*fig.* 677.). The movement of the ribs will obey the same law in receding or approaching each other, and whether they increase or diminish their intercostal spaces, will depend upon the relation they bear to the spine.

Fig. 682. is a cast, from a dissection of the thorax of a male subject, weight 107lbs., height 5ft. 4in. This correctly represents the natural position of the ribs, when the thorax is in a state of complete expiration, or with only the residual air in the lungs. The position of the ribs is very oblique; the spine is curved; therefore the relation of the ribs to the spine is different according to the curve, as are the bars to the body representing the spine (*fig.* 679.). It will be seen that the inferior six or seven ribs are at a more oblique angle to the spine than the superior ribs. The spine does not curve sufficiently to bring the upper ribs to an angle of 90° with the spine; therefore, if all the ribs were raised simultaneously, they would all increase the breadth of their intercostal spaces, whilst their sternal end would recede from the vertebræ, and thus, by their elevation, the thoracic cavity would be enlarged, until they attained the angle of 90° to the spine. But if the elevation were carried beyond this point, the intercostal spaces would diminish, and thus the thoracic cavity would decrease. *Fig.* 684. is a posterior view showing the sloping position of the ribs more clearly. Now, if the spine were perfectly erect, the ribs would have a greater range, and consequently the upper ribs could be elevated higher, and thus still more increase the thoracic cavity. A man can expire a greater volume of air when perfectly erect, than in any other position. On the other hand, if we curve the spine, we limit the divergence of the ribs, because then we bring the ribs more into the position of *a b* and *a′ b′* (*fig.* 678.). Thus, in diseases of the spine, when angular curvature is extensive, the ribs are materially limited in their capability of increasing the perpendicular depth of their intercostal spaces, and consequently the perpendicular depth of the thorax.

Fig. 666. is an instance of angular spine, reducing the ribs to their minimum distances without their moving. We have found by experiment, that the greatest volume of air which persons with angular spine can expire, is little more than equal to the volume of air of an ordinary respiration; *i. e.* from 20 to 40 cubic inches, instead of 180 to 200 cubic inches.

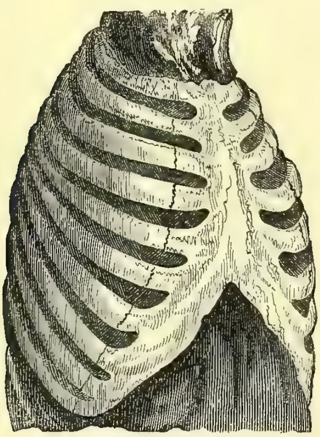
The following experiment proves that the ribs are all elevated when the chest is inflated, and that the spine is straightened. Into the thorax (*fig.* 680. *et seq.*) we insufflated, or forced into the lungs 310 cubic inches of air, and a second cast was taken. The changed position of the ribs and spine is represented in *figs.* 681. 683. and 685. where it will be seen that all the ribs are raised; their perpendicular distances or intercostal spaces are all increased, and the spine is more erect.

This experiment, therefore, demonstrates two things: 1st, that by artificially inflating the chest, the intercostal spaces are widened, and 2dly, that the spine becomes more erect. It is an experiment most unfavourable for showing these two points, because the altered shape of the thorax by insufflation is not to be compared with the exceedingly enlarged condition produced by vital inspiration; in which case the spine becomes more erect, and the intercostal spaces consequently wider. By placing the fingers in the intercostal spaces of a living subject during deep inspiration and expiration, it may easily be perceived that in the former they widen, and in the latter they collapse. From 3000 observations we have found that, in deep inspiration, the body becomes more erect, and less so in expiration.

Insufflation is not the same, in effect, as inspiration. In the former we *force* air into the chest, until the parts most yielding, as the diaphragm and abdominal parietes, are rendered so tense that their tension is sufficient to overcome the elastic force of the ribs, their cartilages, and the lungs; then, and not until then, do we move the costal part of the thorax. On the other hand, in the living and deep inspiration, we lift the ribs and sternum, the most unyielding portions, first. These solely produce the threatened vacuum which inflates the lungs, whilst very little, if any, is accomplished by the diaphragm.

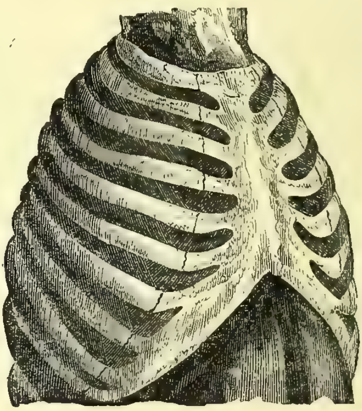
The following table shows the measurements of the thorax, when expanded by inspiration and insufflation.

Fig. 680.



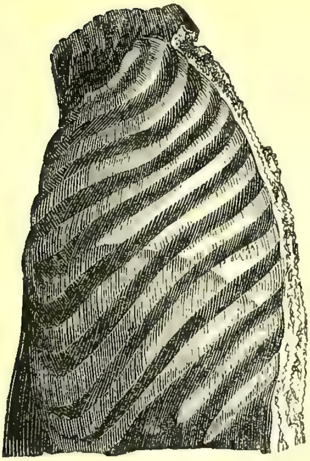
Thorax as at death.

Fig. 681.



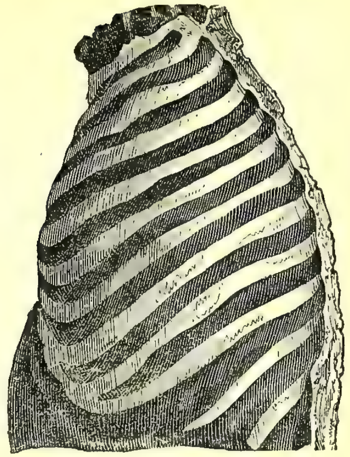
Thorax artificially inflated with air.

Fig. 682.



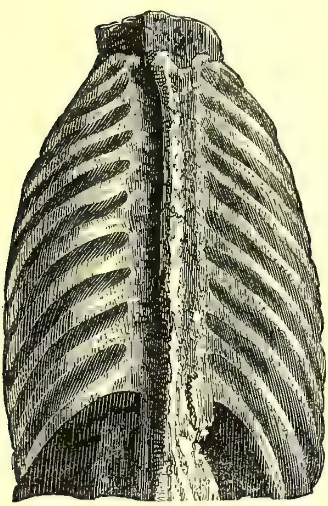
Thorax as at death.

Fig. 683.



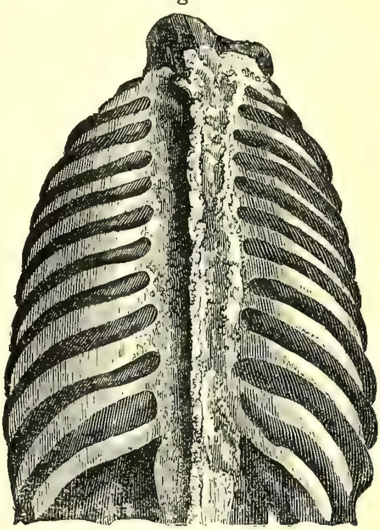
Thorax artificially inflated with air.

Fig. 684.



Thorax as at death.

Fig. 685.



Thorax artificially inflated with air.

TABLE G.—Table of the Dimensions of the Thorax and Abdomen, in the Dead and Living Subject, with the same Quantity of Air distending them.

	Thorax.			Abdomen.		
Conditions at the time of observation.	Circum over nipples.	Diam. lateral.	Diam. ant.-post.	Circum.	Diam. lateral.	Diam. ant.-post.
	in.	in.	in.	in.	in.	in.
DEAD—Natural collapse	$29\frac{3}{4}$	10	8	$29\frac{1}{2}$	$8\frac{3}{4}$	$7\frac{7}{8}$
Insufflated	$31\frac{1}{4}$	$10\frac{1}{2}$	$8\frac{3}{8}$	$31\frac{1}{8}$	10	$9\frac{5}{8}$
ALIVE—Expiration	32	$11\frac{1}{4}$	$9\frac{3}{8}$	25	$10\frac{1}{4}$	$7\frac{3}{4}$
Inspiration	37	$12\frac{1}{4}$	$11\frac{6}{8}$	$25\frac{1}{4}$	11	$8\frac{1}{8}$
Difference—						
By insufflation, dead	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{6}{8}$
By inspiration, alive	5	1	$2\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$

These facts show that we should be guarded in determining the living respiratory movements by experiments upon the dead subject.

It should be constantly borne in mind, that to increase or diminish an intercostal space is to elevate or depress the ribs, and that to elevate or depress the ribs is to increase or diminish their intercostal spaces: the one cannot be accomplished without the other. Some authors have spoken of these as distinct; thus, that in inspiration the superior ribs approximate each other, whilst they are raised, or that their rising or falling does not necessarily involve an increase or diminishing of the intercostal spaces; but these two changes are simultaneous and cannot be done separately.

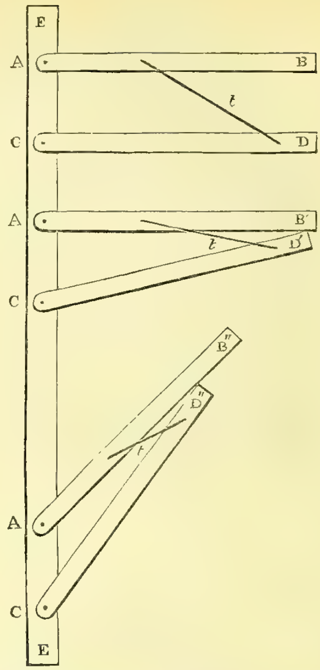
2nd. *The effect of tensions, oblique, perpendicular, and decussating, between the moveable levers or ribs.*—We employ a strip of vulcanised Indian-rubber for a force representing muscular contraction. A strip of this substance, of uniform thickness, $\frac{1}{4}$ of an inch broad and 10 inches long, increased its length, with an increasing weight, as follows:—

Weight in ounces.			gr.	Increased length of Indian rubber. inches.
1	+ the pan holding the weight = 850gr.	=	$1287\frac{1}{2}$	$\frac{1}{2}$
2	do.	=	1725	$\frac{3}{4}$
4	do.	=	2600	1
8	do.	=	4350	$1\frac{3}{4}$
16	do.	=	7850	4
32	do.	=	14850	$12\frac{1}{2}$
64	do.	=	28850	$28\frac{1}{2}$

Although not exactly in accordance with the law of perfect elasticity, yet it is roughly so and enough for our purpose, viz. the tension is greatest when most stretched, and weakest when least stretched, corresponding with muscular contraction.

Let E E (*fig.* 686.) be fixed, A B and C D two moveable bars as before, *t* an oblique tension; if *t* shortens, it has been supposed that the two bars would assume the position of A B′ and C D; but not so: they *both* rise like A B″ and C D″ until the two bars touch each other.* If we prevent this touching of the two bars by a rigid link, like that on parallel rulers, placed as at S *fig.* 687., then the tension will still raise the bars to O O′. In this experiment three circumstances may be noticed. 1st, that the bars have been elevated; 2dly, that the perpendicular distance between them has been diminished; and 3dly, that the tension *t* has been shortened in attaining the position O O′. Place the tension in a *contrary* direction, as between the bars A′ B′ and C′ D′, and the bars are brought into a contrary position, —drawn downwards to O′ O‴. This can be

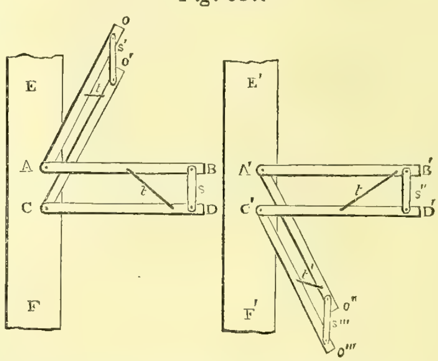
Fig. 686.



Effect of oblique tension on separate bars.

demonstrated by a model, using a spring or Indian-rubber as the tension, and may be

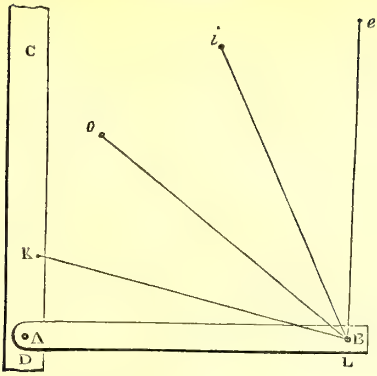
Fig. 687.



explained as follows. Let A B, *fig.* 688., represent one bar, C D the perpendicular fixed body; B is the free extremity of the bar; K an axis from which a parallel bar has been removed. Let *e*, *i*, and *o* be other fixed points; connect *e* to B by an elastic tension, and the bar B will be moved towards *e*. Let the tension be fixed at *i* or *o*, still the bar B will be raised towards the respective points. Let the tension be fixed at K (the centre of motion of the bar which we suppose is removed), and still the bar A B will be raised upwards towards K, and assume the position of A B, K L (*fig.* 689.) at *M*. But it is not necessary to this that the elastic force should extend from

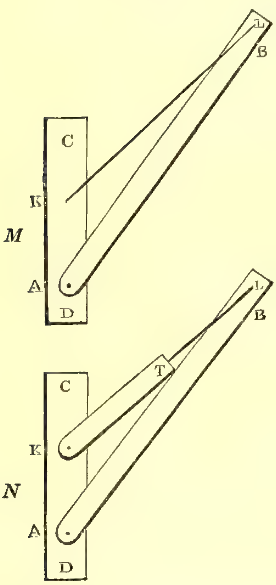
* This appears to have been known to Hamberger; but the author of this article was not aware of it until four years after he first introduced this movement to notice. (See Med. Chirurg. Trans. vol. 29, p. 213.) It is certain that Hamberger's views were not taught in any physiological school in this country, Germany, or France, nor noticed in any of our philosophical works.

Fig. 688.



K to L in order to produce this motion: half of it might be wood, bone, or iron, provided the other half retained its elastic power. The effect would be the same, and the bar A B at *N* would be elevated *by the tension* between T L,

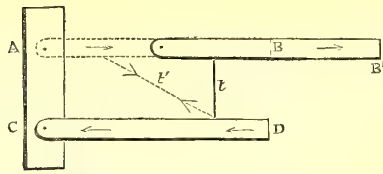
Fig. 689.



connecting the fixed point K with L by the rigid body K T. It is the omission of the fulcrum K, in calculating such oblique forces, which has hitherto obscured the explanation of the intercostal muscles.

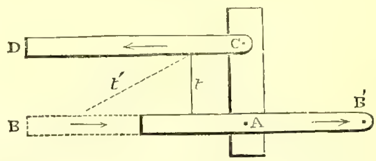
This may be illustrated in another way (*fig.* 690.). Let A B and C D represent bars as before upon A C; t' the tension; let C D and A C be fixed; withdraw the pin at A, and the bar A B is drawn *forwards* into the position B′, and the tension t becomes perpendicular to the two bars. On the other hand, reverse the experiment, as in *fig.* 691.; supposing C D and the perpendicular body C A fixed, withdraw the pin at A, and the bar A B is drawn *backwards* to B′. This presupposes the bars kept apart,

Fig. 690.



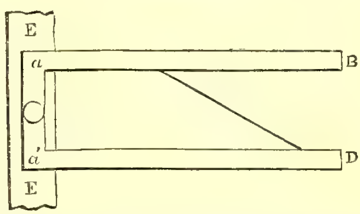
otherwise the free bar would approximate the fixed bar C D. Therefore, one fulcrum is pushed upon by one bar, and pulled upon by the other. If the bars were kept *fixed*, and the body representing the spine was left *free*, the tension would draw this last mentioned body into the

Fig. 691.



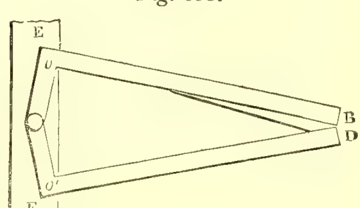
position of c c and c' c' *fig.* 678. Therefore, the element of the two fulcra is the chief agent for directing their upward or downward movement, under an oblique tension. If we arrange two bars with one fulcrum (*fig.* 692.), and allow

Fig. 692.



the tension to act as before, then the effect is only to draw the two bars together, as o b and o' d (*fig.* 693.). If we have an arrangement to substitute two fulcra at a a' *fig.* 692. and withdraw the centre fulcrum, then the two bars rise as before.

Fig. 693.

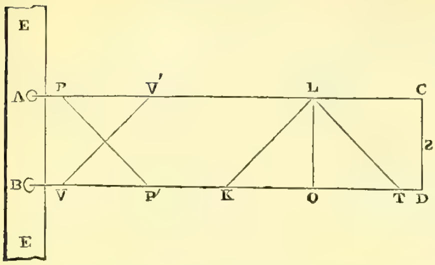


Now we shall suppose the bars at an angle of 90° to the body representing the spine.

A perpendicular tension (L O, *fig.* 694.) admits, of course, of no variation; oblique tensions admit of two variations:

a, obliquity in contrary directions.
b, degrees of obliquity in each direction.

Fig. 694.



The perpendicular tension (L O, *fig.* 694.) produces but one effect, that of approximating the two bars A C and B D, because the force of L O is acting upon A L and B O, levers of the same length, their movements being the same they would meet in the middle distance at S. But if the bars are kept parallel by a rigid link like S, *fig.* 687. the perpendicular tension would produce no apparent effect upon the two bars. They might be rotated in any direction, and the tension would remain of the same length; for example, in *fig.* 695. let *t* 2 be the perpendicular tension between the bars A B C D, move the bars to S or S', and the tension is the same length. *k k k*, &c., may represent different places in the rotation, at each of which the tension *t* or *k* is the same length, although the bars at S, *t* 2, and S' are at different perpendicular distances from each other. A *rigid* connective, as wood or wire, may be substituted for the tension, an- this will equally allow of the bars being rod tated, and consequently changing their perpendicular distances to each other. Hence it will be seen, that each of the lines *k k k*, are of the same length, although the two semicircular lines describing the revolution of the bars are constantly changing in their relative distance to each othe We then seer. the possibility of having a rigid body connecting two bars, which shall nevertheless recede and approximate each other. From this we may gather, that though the sternum is rigid, and the cartilages, perhaps, ossified, the ribs may nevertheless maintain the capability of altering the breadth of their intercostal spaces.

Perpendicular tension, therefore, like L O, (parallel to A B,) cannot rotate the bars, because they never change their length.

All tensions are oblique which have one of their attachments nearer to the spine than the other, therefore, in *fig.* 694., L K and L T are oblique tensions. An oblique tension, hence, is acting on bars at dissimilar distances from their fulcra; thus in *fig.* 696.,

Fig. 695.

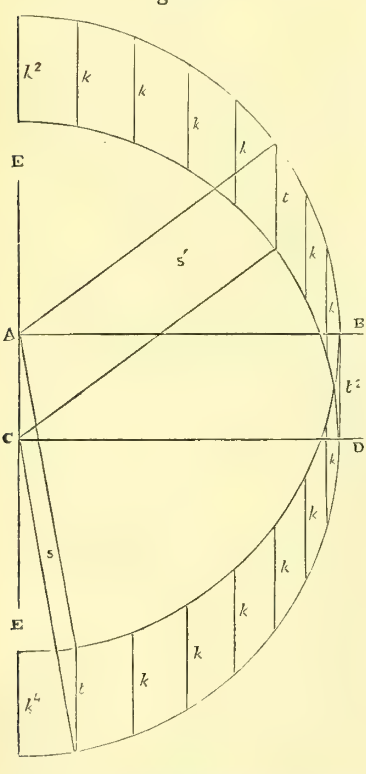
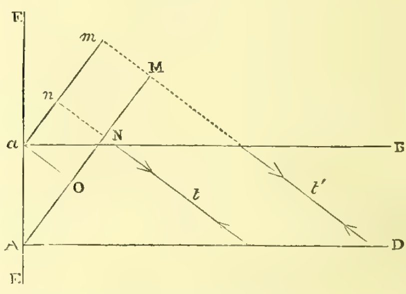


Diagram showing that perpendicular fibres never alter their length.

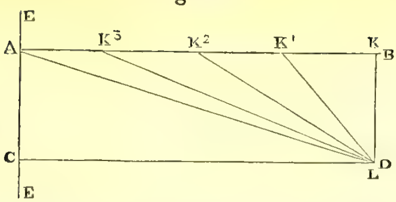
Fig. 696.



tension *t'* is oblique to the line *a* A, and the points on the lines *a* B, A D, to which the tension *t'* is attached, is represented by the lines *a m* and A M. And the law of action of such tension is, that it *tends to move both bars or ribs towards that fulcrum which is nearest to one of its attachments.* Therefore tension L K (*fig.* 694.) would rotate the bars towards B, and tension L T towards A. The force of a given oblique tension between such bars is modified by two circumstances, — by the degree of obliquity, and by the obliquity of the bars in reference to the body which represents the spine.

Of the degree of obliquity of a tension. — Let *fig.* 697. A B, C D, represent bars as before, the different connecting lines tensions of different degrees of obliquity, but of the *same power of tension.* L K is perpendicular, and has no rotating power. L K^1 possesses a certain amount of power, L K^2 more power, and L A the maximum power, or the power of rotating

Fig. 697.



the bars increases with the increasing obliquity of these tensions. By experiment we found that *equal tensions* at the following angles, produced the following difference of power in rotating the bars: —

TABLE H. — Power gained by a given Tension, as an intercostal Muscle, in relation to its Obliquity.

Angle of tension.	Tension.	Resistance.
At 90°	2·5	0
„ 75°	2·5	1·50
„ 46°	2·5	2·25
„ 15°	2·5	4·25
„ 7°	2·5	5·50

The power descreases as the tension approaches the perpendicular L K′, and increases as it approaches L A; this is the maximum point: if the tension be attached to the body E E, either above A or below it, the system is changed into that of a single lever. From this we gather, that the power of an intercostal muscle, as an elevator and depressor of the ribs, *increases* with its obliquity; and that this movement entirely depends upon its obliquity. This is the only instance in the body where the power of a muscle increases with its obliquity.

Of the obliquity of the ribs or bars with reference to the spine. — A given tension, say at the angle of 45°, will, when the lever is at 90° to the spine act more powerfully than when the lever is at an angle similar to that of the ribs. We found by experiment, that the bars in the following positions required an increased power to sustain them. The tension being uniform, and the resistance to be overcome acting from the same point.

This gain of power is dependent upon the obliquity of the bars and change in the direction of the tension, for in each of these positions the tension was maintained the same. But if the tension be not kept uniform, still the resistance is increased as the bars rise; thus, if the bars are at the angle of 50° (*fig.* 699. *m″*) somewhat similar to the position of the ribs, and these under a certain tension allowed to resist a power of 4, when they are moved upwards to 90°, through which revolution the tension has kept diminishing (because it has kept shortening), it will resist a power of 5. In this we see a beautiful compensation to the muscular contraction, viz. that while an intercostal muscle is losing power as it contracts, this loss is made up by the change in *position* of the ribs. We feel conscious that we can exert a retaining power at the termination of a deep inspiration as great, if not greater, than at any other intermediate position of the ribs, at all of which the muscular power actually exerted is greater. All these remarks apply equally if the spine be curved; for change of obliquity of the ribs, or change of curvature of the spine to the ribs, is the same thing.

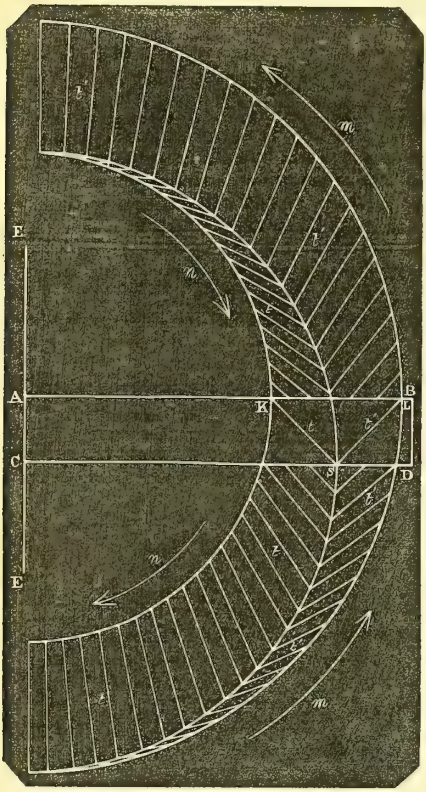
TABLE I. — Change of Power, from the Obliquity of Bars or Ribs to the Spine.

Angles of the Bars with the Body representing the Spine.	Tension.	Resistance.
30°	2·5	4
60°	2·5	12
90°	2·5	22
120°	2·5	33

Of oblique tensions in contrary directions. — We have shown that an oblique tension between parallel levers moves them in a certain course. Now it is evident that tension in a contrary direction (all other things remaining the same) must likewise move such levers in a contrary direction. This is so clear that although Haller asserted absolutely that crossing muscles have the same action, yet he was not comfortable under such an opinion, "for,' says he, "why do they cross?"

We have shown that a tension in the direction of L T *fig.* 694., will raise the bars, and one in the direction of L K will depress them; they are, therefore, antagonistic forces, and when the tensions are similar, they produce an equilibrium of contrary force. If the bars A B, C D, (*fig.* 676.) be rotated, the lines will have directions contrary to each other, and will lengthen and shorten inversely to each other. Thus of the crossing tensions (*fig.* 676.) V D and V′ B, V′ B becomes shortened to *n b′*, and V D, on the contrary, becomes lengthened to *n b′*; and on the other side of 90°, V D is shortened to *s d*, and V′ B lengthened to *s′ b*. Therefore muscles circumstanced like the intercostals and crossing each other, or observing contrary directions to each other, cannot be associates in action, for when one contracts, the other must relax, as the ribs move. We represent this more clearly in *fig.* 698. where A B and C D represent bars as before, rotating upon E, E, and *t t′* two tensions in contrary directions. As the bars are raised towards *m*, *t′* lengthens, and if depressed towards *m′* it shortens, while *t* lengthens towards *n*, and shortens towards *n′*. We represent the tensions *t t*, &c., and *t′ t′*, &c., by the white lines, in the different positions they would assume if the two bars were rotated to those places in the half circle. It will likewise be observed, that while either tension gradually lengthens or shortens, the two bars pass through their *maximum* perpendicular distance from each other at B D, on either side of which they attain their *minimum* distance. Therefore, if we examine tension *t* at *n′*, the bars would there be closer to each other than they are at B D; nevertheless, this tension in ascending must contract while the bars are *increasing* their perpendicular distances as they move to B D; beyond which the tension still shortens, while the bars now *decrease* their perpendicular distance. Therefore it is perfectly compatible for an intercostal fibre to *separate* the two ribs, between which it is attached, by its contracting; and, if above a certain point (90° to the spine), to *approximate* the same ribs by its further contraction.

Fig. 698.



In deep inspiration it will be found that the ribs increase the breadth of their intercostal spaces (as was mentioned years ago by Hamberger); and that by the *contraction* of an intercostal fibre. The bars (*fig.* 698.) in rotating, twice attain a minimum, and once a maximum, distance from each other; while the oblique tension in that revolution once attains its maximum, and once its minimum length.

Of tensions at different parts of the bars or ribs. — Parallel tensions of equal power produce the same effect, whether near the fulcrum or more distant from it; an intercostal fibre near the vertebræ, has the same power as a fibre near the anterior extremity of the ribs.

Let *Fig.* 696. represent ribs as before, with two parallel tensions at different distances from the body, E E, then

$t' + \text{AM} - t' + am = t' + x(\text{AM} - am) = t' + \text{AO}$

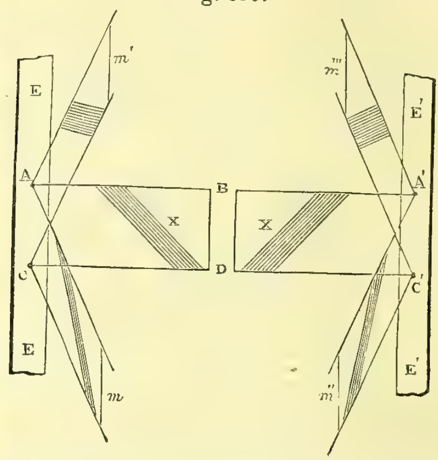
$t + \text{AN} - t + an = t + (\text{AN} - an) = t + \text{AO}.$

Therefore the tension L T (*fig.* 694.) acts with the same power as tensions P P′, which is much nearer to the fulcra A B.

Knowing now the effect of a single oblique tension, it is easy to consider an indefinite number of tensions, for they follow the same law of action.

In *fig.* 699. the tensions X acting on A C, *lift*

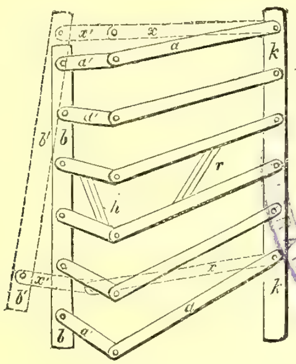
Fig. 699.



the bars to m', and, by the same reason, tentions observing a *contrary* direction and acting upon A′ C′ lift the bars to m'''. Therefore tensions, although observing contrary directions, may be made to conspire to the same action, and may therefore be associates when acting upon different fulcra. We have shown that tensions in contrary directions, but acting upon the same fulcra, are antagonists. If we join the levers (*fig.* 699.) and increase their number, we may represent the thorax as in *fig.* 700., *k k* representing the spine, *b b* the sternum, the bars *a a* the ribs, and the bars *a′ a′* the costal cartilages united to the bars representing ribs by a movable joint; let *r* represent the external intercostals, these, we know, will act as elevators, while those at *h*, representing the internal intercostals, are associates in action, although they observe a contrary direction, because they act upon the fulcra in *b b*; in fact, they are elevators of the levers representing the cartilages.

What now is the combined action of a series of two such tensions? The whole body of levers will be raised, and the part *b b* representing the sternum will have two motions: it will be raised and moved forwards into the position of *b′ b′*. This is precisely the motion of the sternum in deep inspiration. In a model of this kind, certain means must be used to limit the motion, or the movement is continued until the tensions are at rest. Or, if the bars representing the ribs *a a* (*fig.* 700.) be fixed, then the tensions representing the internal intercostals *h* would depress the short bars representing the cartilages, because *b b* is free, and *k k* is fixed. And were either set of tensions continued over the joints representing the union of the cartilages with the ribs, such fibres would antagonise each other. In nature the external intercostals are not continued over to the intercartilaginous spaces.

Fig. 700.



In this model all the ribs are elevated without the first bar being drawn up by any tension representing the scalenii muscles. In fact the fulcra are the fixed points; therefore there are here six fixed points for the tensions to act upon, and hence each row of oblique tensions acts quite independently.

This application of force and disposition of the bars representing the ribs is after the manner of that great engine of power the "genou lever." (*Vide* Potter's Mechanics.)

Tensions in the first space (*fig.* 700.) act with a greater power in pushing out the body *b* than do the tensions in the 5th space; but, on the other hand, the motion is less in the 1st than in the 5th space. It will also be seen that these six bars, though moving all equally, will produce an unequal effect upon the body *b b*, forcing out the lower end more than the upper end. The ribs of man, in the same manner, increase in their length from the 1st to the 8th, and, therefore, by an equal mobility, an unequal protrusion of the sternum is produced, advancing the lower end more than the upper end. We have reason to believe that the mobility of all the ribs is the *same*, and that it is by their different lengths that the different degrees of protrusion of the anterior part of the thorax may be accounted for.

Having investigated the effect of artificial tensions acting on bars made to represent the ribs, we can now return to the consideration of the action of the direct respiratory muscles.

Action of the intercostal muscles (resumed).— The *intercostales externi* are all *elevators* of the ribs. Inspiratory muscles. They separate the ribs in the act, and they can do this independently of any other muscle fixing the first rib. The *intercostales interni* have a double action. All those portions between the *ribs* depress the ribs and are expiratory muscles; they also approximate the ribs and in every way antagonise the external intercostal muscles. Those portions between the *costal cartilages* are elevators of the cartilages, and associates with the external intercostals, and, thence, *inspiratory* muscles. These muscles also can act independently of any other muscle fixing the first or last rib.

The intercostal muscles being antagonists, they yield to each other, the same as any other flexor yields to an extensor muscle. We possess a perfect and definite command over the ribs, and can stop their respiratory movements at any stage of breathing, more readily than we can those of the diaphragm.

It is necessary to healthy breathing that we should raise *all* the ribs; they are therefore all mobile, and all their intercostal spaces are increased in their perpendicular distance during inspiration, and diminished during expiration.

II. *Levatores costarum* (*Levatores breviores costarum*, Alb.).—These are narrow, tendinous, and fleshy fasciculi (*fig.* 672.) covering the posterior end of the rib, and extending obliquely downwards and forwards, in the same direction as the external intercostals. Their superior attachment is to the extremities of the transverse processes of the dorsal vertebræ; their inferior to the margins of the ribs between their angles and tubercles. These fibres spread out and become flat at their insertion. Each rib receives one from the vertebra next above; there are therefore twelve muscles on each side; and that for the first rib is derived from the last cervical vertebra. The inferior muscles of this series divide into two parts; one of which is distributed as above stated; but the other, consisting of longer fibres, passes over one rib and te-r minates on the second below; and thus each of the lower ribs receives muscular fibres from the transverse processes of two vertebræ. The long bands have been described as separate muscles under the name *levatores longiores costarum* (Albinus).

Action.—The same as the external intercostals. Elevators of the ribs and inspiratory muscles. Acting directly upon their fulcra, the transverse processes of the vertebræ.

III. *Triangularis sterni* (*Sterno-costalis*, Verheyen).— A thin flat plane of muscular and tendinous fibres (*fig.* 674.) placed within the thorax, immediately behind the costal cartilages. This muscle is attached to the inner surface of the ensiform cartilage, lower part of the sternum, and the cartilages of the lower true ribs. From these origins its fibres pass laterally along the inner walls of the thorax, diverging upwards, horizontally, and downwards, and are attached by digitations (which give to the outer margin a serrated appearance) into the cartilages, lower border, and inner surface, of each of the true ribs, from the 5th to the 2nd inclusive.

Action. — This muscle varies considerably in the extent and points of its attachment in different bodies, and even in the opposite sides of the same body. Hence, it aids in drawing down and drawing up (according to the direction of its fibres) the ribs. It may be said to be both inspiratory and expiratory.

IV. *Infra-costales* (Verheyen).—In connection with the inner surface of the ribs (*fig.* 673.) several small bundles of fleshy and tendinous fibres, which are thus named, will be found extending over two, and in some instances over three, intercostal spaces. They have the same direction with the internal intercostals, and are (properly) often described as parts of those muscles. The fasciculi vary in size and number, and may be found on any of the intercostal spaces, except, perhaps, the first; but they are most constant on the lower ribs.

Action. — The same as the costal portion of the internal intercostals, depressors of the ribs and expiratory muscles.

Of the elasticity of the ribs. — Elasticity depends upon reaction, and restores in a contrary direction the force which have been impressed; the effect produced is commensurate with the amount of the cause, and the reaction can never take place so long as the cause continues to be applied; but immediately that cause ceases, the elasticity comes into action.

Inspiration is performed by the true inspiratory muscles, and expiration, by the expiratory muscles, and the elasticity of the ribs and their cartilages, together with the elasticity of the lungs. We find a broad difference *manifested* between the inspiratory and expiratory power (Table R.), the latter exceeding former by about one third. This difference is due to the elasticity of the ribs and lungs associating their power with the expiratory muscles. The combined elastic power is very great; we have examined it in two favourable cases, an hour after death, when the bodies had not fallen one degree in temperature.

X. H., a young man, slightly built, erect and well formed, æt. 22, weight $9\frac{1}{2}$st., height 5ft. 10in., vital capacity 235 cubic inches. The absolute capacity of his chest was 248 cubic inches; internal area 256in.; circumference of the chest, over the nipples, in the ordinary state, alive 33 inches, dead $30\frac{1}{2}$ inches. After death we forced air into his lungs, whilst the temperature of the body was still at 97°. The force resisting the introduction of this air must havebeen due to the elasticity of the ribs and their cartilages, together with that of the lungs. By an arrangement, we could force in different quantities of air, and measure the collapsing power of the elastic parts, through the medium of the confined air pressing upon a column of mercury: the following was the result:—

Table K. — Costal elastic Collapse.
X. H.

	cub. in.		Inch of mercury.
Air forced in	70	Resisting elasticity	1·20
Ditto	90	ditto	1·25
Ditto	160	ditto	2·50

We could not force in more air, for with this pressure it was impossible to prevent the air escaping with great rapidity through the necessary wounds. This experiment was repeated three times with the same result. It will be remembered that X. H. had drawn into his lungs, when alive, 75 cubic inches of air more than we could force in, after death. If, therefore, 160 cubic inches produced a collapsing elastic force equal to 2·5 we may suppose that 235 cubic inches would produce an elastic force equal to not less than 3·9 in. of mercury. This chest, measuring 256 superficial square inches, it follows that X. H., in breathing out 235 cubic inches of air, with no more sensible effort than that of a mere sigh, had to overcome with his inspiratory muscles a gross elastic resistance of about 499lbs., and with a force equal to this weight would the thoracic walls recoil for expiration upon the air in his lungs.

N. C., height 5ft. 8in., weight 10st. 10lb., æt. 21: vital capacity, 200 cubic inches; *absolute* capacity, 245 cubic inches; superficial measurement of the entire thoracic cavity, 256 square inches; circumference of the chest, alive, 33 inches, dead, $34\frac{1}{2}$. Temperature of the body, when examined, 97° F. Temperature of the air forced into the lungs, 63° F. This man was what is termed "thick set," firm, erect, and well built, a porter by trade, a very different case from the former. The following was the elastic power of his ribs: —

Table L. — Costal Collapse in N. C.

	cub. in.		Inch of mercury.
Air forced in	70	Resisting elasticity	1·00
Ditto	90	ditto	1·50
Ditto	180	ditto	3·25
Ditto	200	ditto	4·50

The first ninety inches of air introduced ruptured the lungs; therefore the elasticity of the lungs did not interfere with our experiments. In both cases this resistance must be referred only to the ribs, their cartilages and ligamentous attachments; also, in both cases, the bodies were kept erect, or in the sitting posture; this should be attended to, for the mere weight of the body upon the ribs when recumbent would increase their collapsing power.

These tables express a dead power always in reserve, equally powerful whether we are in robust health, or emaciated by age or disease. Dead or alive, this is ready to be put into force; and, in fact, it is never at rest, never at zero, until death; we may even go farther, and say, not until decomposition has weakened the collapsing tension of these parts. Cut through a costal cartilage, or take out a small portion of the sternum, say corresponding to the 3rd, 4th, and 5th intercostal spaces, and the opening by the elasticity of parts will *retract*, and we never can restore them again to their original fit, because the thoracic parietes are still not at rest. The bony cage-work of the chest is so tightly knitted together, that at its minimum contraction there still remains an elastic force in operation. In fact we might expect this, because the respiratory movements are so small that it is necessary that an extensive elastic power should be ready at *all* the respiratory stages; and therefore the parts are upon the stretch *before* we begin to inspire in order to increase to the geometrical degree required, of two, three, or four pounds to the inch, by a very limited movement, which would not be the case did we begin to inspire when the thoracic boundaries were at zero, at least, if it did, the walls, &c., would have to be much stronger.

Supposing inspiration to be the result of muscular force equally distributed over the whole thorax, the inspiratory power is easily calculated. Taking the walls of the chest at 206 superficial inches, and the area of the diaphragm as 51 superficial inches, and placing them separately, it would appear as follows:—

Table M. — Inspiratory Muscular Power required to overcome Costal Elasticity, measured by the Insufflation of 200 Cubic Inches of Air. (Case, N. C.)

Air forced into the Chest.	Resistance manifested by Inches of Mercury.	The same reduced to Ounces on the superficial Inch over the Thorax.	The same, given as a total Force in lbs.	Total Power required by the Diaphragm to resist the Collapse of the Ribs, in lbs.	Total Powers of the Walls and Diaphragm conjoined, in lbs.
70	1·00	7·8	104·4	24·8	129·2
90	1·50	11·7	150·6	37·3	187·9
180	3·25	25·3	326·3	80·6	406·9
200	4·50	35·1	451·9	111·8	563·7

At the same time it must be remembered that this result is produced by insufflation which would excite an undue elastic tension in the diaphragm and abdominal muscles. Yet, on the other hand, in life a greater expansion would be produced by the ribs, and thence a greater resistance.

It may be questioned how far we are entitled to add a resistance as due to the diaphragm. But let us suppose a thoracic cavity collapsed to rest, with a fleshy floor or diaphragm also quiescent; let us suppose the ribs expanded by some power from without; the air within the chest would be attenuated, and the diaphragm would be forced upwards, by atmospheric pressure, with a force exactly commensurate to the rarefaction of the air within the chest (presupposing that no air is allowed to enter the chest when we expand the ribs). In this case the diaphragm is resisting the same force per inch as the walls of the chest. Or on the other hand, fill the chest with air to perfect distension, allow the ribs to collapse, the diaphragm would have to resist this collapse with a power exactly commensurate with the recoiling elasticity of the ribs; therefore the diaphragm participates, in common, in such resistances in the thoracic cavity. But, as the question may be open to objection, we shall chiefly notice that power in reference to the parietes of the chest, given in the 3d and 4th columns in the last table. This table shows that the man, when alive, exerted a muscular power with the walls of the chest, when he inspired 200 cubic inches of air, equal to a total weight of 451·9 lbs. avordupois. Independently of the collapsing elasticity of the lungs, which would be not less than 128 lbs. more (see Table O), his inspiratory muscles lifted a weight of 32 stones, — a weight which he could not have lifted with his arms: and yet the animal economy is not conscious of this exertion. We have supposed a uniform muscular traction, which is not the case, because the distribution of muscular fibre and thoracic mobility, is not equally applied in expanding the chest. In diagram *fig.* 670, D represents a section of the thorax: the portion shaded is the range of thoracic mobility between extreme inspiration and expiration. The mobility is unequal; more is on the anterior than on the posterior part; therefore we may presume muscular traction to be more at one part than at another. This man could exhale 300 cubic inches of air; and there is every reason to think, from this extensive mobility, according to our last estimate, that the elastic collapse of his ribs, at the termination of deep inspiration, would be not less than 1000 lbs.

In the superficial measurements of the thorax we have included every part, even that covering the vertebræ. Now certainly we cannot think the elastic collapse over the vertebræ equal to that from the sternum; therefore, if we allow one-third of the chest to be inactive, and the remainder elevated by the respiratory muscles (which we think is within the mark, because *every* part of the chest is mobile), then in the case of N. C. in deep inspiration the muscles would have to overcome 301 lbs., or 23 ounces on the superficial square inch of the thorax.

The last act of life is a deep expiration. During life the ribs are always kept under a certain degree of distension, which is ready to send out from 70 to 100 cubic inches of air at any moment (*Reserve air*, p. 1067). Our inspiratory muscles, in fact, are always antagonising an elastic thoracic collapse; and this is always increasing or decreasing, according to the stage of respiration, as quiescent or forced, &c. There are cases, as in hanging, where a man may die, at the moment of full inspiration, from fear, making an effort to resist the dreaded shock which he is about to receive. N. C. died thus in a state of inspiration. Making allowance for unequal elasticity of the boundaries of the thorax, of $\frac{1}{3}$ as above stated, it may be safely said that the different stages of respiration or breathing require the following muscular power to antagonise the elastic power of the ribs throughout life.

Table N. — Inspiratory Muscular Power (corrected).

	Different stages of inspiration.	Elastic resistance in ounces on the superficial square inch to be overcome by the respiratory muscles.	Total resistance of the same in lbs.
1st case X. H.	Reserve air	5·6	69·6
	Breathing air	7·8	104·4
2d case N. C.	Vital capacity	23·9	301·0

Thus we see that in the mere act of *ordinary breathing* there is an elastic resistance, *independently of the elastic force of the lungs*, equal to more than 100 lbs. This is to be lifted 18 or 20 times every minute of our life.

Of the Elastic Power of the Lungs. — Independently of the powerful collapse of the ribs and their cartilages, expiration is greatly aided by the *elasticity of the lungs* themselves, which at all times, and in all the stages of respiration, are tending to collapse upon themselves; and hence, immediately upon puncturing the thorax, the lungs collapse to half their dimensions.

From the earliest period of physiological research, as usual, totally opposite opinions have alternately prevailed as to whether the lungs themselves are active in the respiratory movements. Averroes, Riolan, Planter, and Bremond*, were in favour of their independent action; and Bartholin, Diemerhoeck, Mayow, and Haller†, opposed to it. Their elastic contractility can only have been lost sight of by reason of their quick contractible power; for immediately the thorax is punctured, before parts are cleared away sufficiently to give a view of the contents of the thorax, the lungs have collapsed to their minimum, and a vast space is always presented between the lungs and the thoracic walls, which, by the old anatomists, even in the time of Hoadly (1740), was considered to contain air necessary for respiration.

Dr. Carson of Liverpool appears to have first noticed this elastic power of the lungs. He judiciously observes: "Breathing is, in a great measure, the effect of this interminable contest between the elasticity of the lungs and the irritability of the diaphragm."‡

In his experiments upon the lungs of some lower animals (bullocks), he found a collapsing power equal to a column of from 12 to 18 inches of water; in a calf about 18 inches; and in a dog about 10 inches.

In these experiments, the lungs, when *in situ*, were inflated to their maximum. Probably the ribs interfered by their resistance in aiding the collapse of the lungs. Nevertheless, at all times of inflation, even when the residual volume only was in the lungs, there was an elastic power in operation. Mr. Gulliver informs us, that from an examination of the lungs of man and the lower mammalia he has been led to infer that the elastic tissue is an important agent in expiration. This tissue, he says, may be seen to invest the entire surface of the lungs, forming a strong, elastic, though delicate, capsule to the organ. This investment of the lungs in the horse, he informs us, resembles the fibres of the ligamentum nuchæ and the fibrous coat of the aorta of the ox, as depicted in Gerber's Anat. pp. 54, 55.

The longitudinal fibres which enter into the structure of the air-tubes throughout their entire extent are very elastic, like the coats of the arteries, and these are justly supposed to possess the power of contracting each minute ramification of the lungs. When this elastic power is at rest, and the lungs are collapsed to their minimum, no external pressure can discharge the remaining volume of air, because the very pressure, to accomplish this, compresses the exit tube in some part of its course. The elastic contraction of each tube acts somewhat like the vermicular motion of the intestines, causing a specific diminution of calibre upon each part of the column of air in a ramification, driving it forward. But when the elasticity has arrived at its minimum, and this tissue is quiescent, we cannot extract any more air from the lungs, because the vermicular expelling power derived from this elastic tissue ceases to act. The collapsing power of the lungs acts in the same direction as that of the ribs, but with less force.

According to Tables O and P. the total elastic collapse of the male lung was equal to about 4301 grs. or nearly 10 oz. avoirdupois (9·8) upon the superficial square inch of that organ, and in the female about 5060 gr. or 11·3 oz. upon the superficial square inch. We think, taking all things into consideration, that it is safe to say, in making a deep inspiration for the vital capacity-volume, that we may estimate the elastic collapsing power of the lungs at one half lb. avoirdupois, per superficial square inch; therefore, allowing the mean superficial measurement of the male lung to be 300 in. and the female 247 in., that the *gross resistance*, by the elasticity of the lungs against the inspiratory muscles, would be in the male 150 lbs., and in the female 123 lbs. This is to be added to the elastic force of the ribs (Table N). In the female an unknown portion of the residual volume escaped before we could connect the hæmadynamometer; for the next volume added, of 90 cubic inches in the man with all his residual volume, the collapsing power was 7·2 in., and in the female, with the addition of 100 cubic inches, it was 5·5 in., which about makes up the difference of 2 in. of collapsing power lost by the accidental escape of the residual volume.

In the case of two healthy persons examined *immediately* after death,— E. F. M., male, height 5 ft. 9 in., weight 10 st. 10 lbs.,

* Mém. de l'Acad. des Sciences, Paris, 1739; Müller, p. 346.

† El. Phys. t. iii. l. viii. p. 226.

‡ Phil. Tr. 1820, part i. pp. 42, 43.

circumference over the nipples, alive, 38 in.; dead, 36 in. — died with an expiration, — we, by means of the hæmadynamometer, containing *water*, attached to the trachea, found, with different volumes of air in the lungs, the following elastic collapsing power (temperature — of body 98·5° Fahr. — of atmosphere 59·5°, barometer 29·753).

Table O. — *Elasticity of the Lungs* (male, æt. 29.).

* Volumes of air.	Elastic collapsing power, in. of water.
Residual vol. - - - -	2·5
Reserve vol. (+90 cubic inches)	7·2
Breathing vol. (+20 ditto)	8·2
Vital capacity (+25 ditto +150 ditto) - - - -	17·0

M. M., female; sudden death; temperature of body 97·5° Fahr.; æt. 28; height 5 ft. 9 in.; circumference of chest over nipples 37 in.; below $32\frac{1}{4}$; lungs healthy.

Table P.—*Elasticity of Lungs* (fem., æt. 28.).

Volumes of air.	Elastic collapsing power, in. of water.
Residual vol. - - - -	0·7
Reserve vol. (+ 100 cubic inches)	5·5
Breathing vol. (+100 ditto)	10·0
Vital capacity (+ 90 ditto)	20·0

At the commencement of "ordinary breathing" the collapsing power of the lungs in our experiment was 7·2 in., or nearly $\frac{1}{3}$ of a lb. per superficial square inch. This is a very notable power, not less in the gross, oftentimes, than 100 lbs. of dead uncounterbalanced resistance to the respiratory muscles. In the female, with nearly an arithmetical increase of 100 cubic inches per volume, the collapsing power increases 5 to 10 and 20. The insufflated volume in the male being less regular, the collapsing power manifested is also less regular. But, taking the mean resistance of the reserve and breathing volumes in the male combined (160 cub. in.), the power of collapse was 7·7 inches. In the female, the mean of nearly the same quantity of air in the lungs (within 10 cubic inches) allowing for little or no residual volume at the starting point when we inflated, is likewise 7·7 inches. We believe that the elastic power of the lungs in the two sexes is the same; — indeed why should it not be so? because the office of the elastic tissue is to drive out of the lungs volumes of air no longer required; and it is probable that the resistance given by the air, against the sides of the air tubes, in both sexes, is the same; and unless the number and calibre of the air tubes are different, the resistance, by friction, to the elastic collapse of the lungs, from the transmission of similar volumes of air in the two sexes, must be the same.

In three experiments we found the elastic collapse of the lungs cease at different degrees; *i. e.* different volumes of residual air were displaced when the elastic force had come to its minimum.

* For definition of these terms see p. 1065.

Table Q.—Volume of Residual Air displaced by the Elastic Collapse of the Lungs when the Thorax was opened, in three Males.

	Height.	Weight.	Circum. of chest.	Weight of Lungs.	Vital capacity.	Volume displaced.	Bronchial expansion.
	ft. in.	st. lbs.	in.	lbs.	in.	in.	in.
H.	5 10	11 10	$30\frac{1}{2}$	—	240	30	7
C.	5 8	10 10	$34\frac{1}{2}$	$16\frac{3}{4}$	200	60	1·5
M.	5 9	11 0	36	36	238	45	12·5

There is no order in the numbers 30, 60, and 45, relative to the other measurements. We do not know what quantity of air remained after these volumes were displaced. When we exhausted the remainder of the residual volume, which is not affected by the elastic collapse of the lungs, the sides of the air tubes themselves collapsed by the atmospheric pressure. They likewise are elastic, but in a *contrary* direction; an expanding elasticity keeping them open. We found that the *expanding* elasticity acted so as to draw or suck inwards the air with the different powers represented by 7, 1·5 and 12·5 inches of water in the hæmadynamometer, when we attempted to withdraw out of the lungs more air than the lungs themselves naturally displace by their collapsing elasticity. Therefore these figures may represent the expanding elasticity of the air tubes. In these cases there is no apparent order; but we learn the fact that such elasticity exists. In the case C there was a tubercular condition of lung, in the milliary form, in one apex; in H there was extensive pleuritic adhesions; but in the case of M the lungs were remarkably healthy. It is interesting to notice that there are here two elasticities in contrary directions, — an elastic collapse which has its limit at a certain point, and an elastic expansion of the air tubes, which likewise have their limit of *expansion* at the same point, protecting the calibre of the air tubes from any further collapse.

In the case of M the *expansion* of the air tubes was equal to 12·5 inches of water; by calculation it appears that the *collapse* of the elastic tissue upon the vital capacity volume would be about 14 inches. These antagonistic forces are quite independent of the will, or any nervous stimuli: one is for maintaining an expiratory current of air, and the other for preserving an open channel in the lungs for inspiration.

The lungs are very delicate organs, and can resist but little artificial force; for, if once inflated to the ordinary state of either the breathing volume or vital capacity volume, they do not appear able to collapse again to their original size; — probably intra-lobular emphysema is produced.

In our experiments we forced air into the lungs; they were expanded because we inflated them. We now think it would be better to inflate them by *expanding* them (removing the external atmospheric pressure), and allow the air to drop into the air vesicles by its own gravitation (as in living respiration), when they would in all probability collapse freely to their original position. When they are inflated by expansion (the natural way of life) the delicate cells of the lungs can safely resist a force of from 3 to 9 inches of mercury, or from 40 to 121 inches of water (see next column); but when *expanded by inflation*, their collapsing power was damaged so that it could sustain only 17 or 20 inches of water. This is worthy of notice in resuscitating the apparently asphyxiated person, at which times we have long been of opinion that bellows and pumps are highly dangerous instruments to use for maintaining artificial respiration.

Of the muscular contractility of the lungs. — In the trachea transverse muscular fibres extend across posteriorly, connecting the tips of the incomplete rings of cartilage. In the smaller bronchi they encircle the whole tubes, and there appears to be little doubt but that these circular fibres are to be found in every part of the air tubes as far as the terminal air vesicles.

Physiologists have disputed whether these fibres are muscular or not; if muscular, they are important agents in respiration, acting as a series of little expiratory muscles.

Dr. C. J. B. Williams lately read a paper at the meeting of Glasgow (September 1840), upon the subject.* He experimented upon the lungs of some of the lower animals, — several dogs, a rabbit, a bullock, a horse, &c., — as soon as possible after death, submitting their lungs to galvanic stimuli, and securing a hæmadynamometer with a stop-cork to the trachea. He found that, upon applying this stimulus, the fluid in the bent tube *rose* from 1 to 2 inches, and it *immediately fell* on breaking contact. This effect could only be produced by muscular contraction.

Kölliker, a very accurate observer, confirms these views.† He found in man, in the larger and finer bronchial tubes, a coat formed of annular fibres, in one or more layers according to the size of the tube, consisting of unstriped muscular fibres; and over this coat a thin layer of fibro-cellular tissue with nucleus-fibres. He found no muscular fibres directed longitudinally. He observes, "In former observations I thought I had convinced myself of the existence of unstriped muscular fibres in the air-cells; but in my resumed examination of the lungs of man and mammalia, I can with certainty see nothing distinctly characteristic as such muscular tissue." Our knowledge of these circular muscular fibres was first chiefly derived from the researches of Reisseissen. Laennec considered spasmodic asthma to be assignable to a spasm of these circular fibres. We are as yet ignorant of the possible extent of contraction of these fibres. The discharge of air is paramount, and that from the most remote vesicle; and we know that by no mechanial means can we obtain this, and therefore a molecular power is necessary, which we readily imagine can be obtained by these tissues acting so as to give a peristaltic motion, and thus displacing from every individual vesicle the delicate stream of air necessary to be discharged. We do not need these tissues for inspiration, because the atmosphere, by its mere weight, can penetrate into the most remote air-cell, overcoming all the friction against the sides of the air-tubes. The inspiratory volumes of air are but for one purpose, to aërate the blood; but the expiratory volumes are for the voice and other purposes sometimes requiring great force to aid in certain expulsive efforts.

* The Pathology and Diagnosis of Diseases of the Chest, 8vo. by Dr. C. J. B. Williams, 1840, London, p. 320.

† Beiträge zur Kenntniss der glatten Muskeln in the Zeitschrift für Wissenschaftliche Zoologie, H. i. S. 40. 8vo, 1848.

Of Respiratory Muscular Power. — Young falls into an error in supposing "that in muscles of the same kind the strength must be as the number of fibres, or as the extent of the surface which would be formed by cutting the muscle across; and it is not improbable that the contractile force of the muscles of a healthy man is equivalent to about 500 lbs. for every square inch of the section."* When we examine men we find no such calculations are to be relied upon. It is very common to find two men of corresponding dimensions produce very different effects upon any dynamic instrument.

The respiratory power may or may not correspond with the general development of muscular force.

We have submitted 1500 men of various classes to an experiment upon the inspiratory and expiratory power. The resistance to this power was a column of mercury,—the *hæmadynamometer*, or bent tube, first used by Dr. Hales. He observes, "A man, by a peculiar action of his mouth and tongue, may suck mercury 22 inches, and some men 27 or 28 inches, high; yet I have found by experience that, by the bare *inspiring* action of the diaphragm and dilating thorax, I could scarcely raise the mercury 2 inches."† Hales apparently never tested the expiratory power.

We connected the column of mercury with the index on a dial plate, which represented the inches and tenths of inches of mercury lifted. A tube was adapted to fit the nostrils through which the inspiratory or expiratory effort was made. By the former the index was moved in one direction, and by the latter in the contrary direction; each half of the dial plate representing, respectively, inspiratory and expiratory power, with expressive words attached, as follow: — (See top of next page.)

It will be observed that the figures on each side of the same word differ in their value, those of the expiratory side ranging about one-third higher than those on the inspiratory side.

* See Nat. Phil. Lond. 8vo, 1845, p. 99.

† Stat., vol. i. p. 267.

Table R.

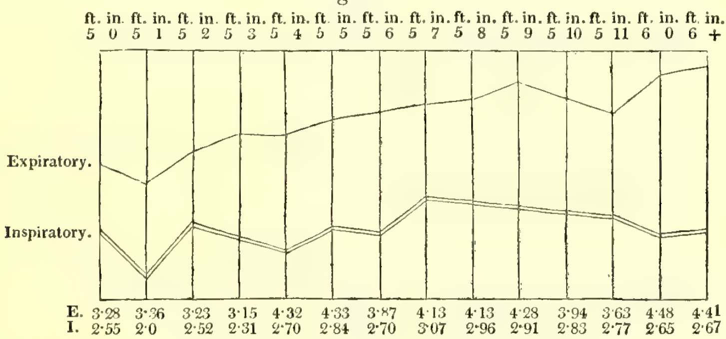
Power of Inspiratory Muscles.		Power of Expiratory Muscles.
1·5 in.	Weak - - -	2·0 in.
2·0 „	Ordinary - -	2·5 „
2·5 „	Strong - - -	3·5 „
3·5 „	Very strong - -	4·5 „
4·5 „	Remarkable - -	5·8 „
5·5 „	Very remarkable -	7·0 „
6·0 „	Extraordinary - -	8·5 „
7·0 „	Very extraordinary -	10·0 „

Indeed when these powers are the same, it indicates *disease*. We subjoin the following table of the result of these cases. (Table S.)

To illustrate one of the points so striking in these experiments (viz., the difference between the inspiratory and expiratory power), we refer to diagram 701., which represents by curves their relative position. The upper line is the expiratory power, and the double line below, the inspiratory power. The perpendicular lines are the different heights of the cases examined. The position of these curved lines indicates the power they represent, — the higher the curve the greater the power. The two rows of figures at the bottom are the inches and tenths of inches of mercury elevated. (I. for inspiration, and E. for expiration.)

According to this, at the height of 5 feet 7 inches, and 5 feet 8 inches, the inspiratory power is greatest, and thence the inspiratory power gradually decreases as the stature increases. The men of 5 feet 7 inches and 8 inches elevate a column of 3 inches of mercury: this may be considered a healthy power; and the men of 6 feet high elevate about 2½ inches of mercury as their healthy power.

Fig. 701.



Inspiratory and expiratory power in healthy cases.

It may be asked, why connect this with the height? Because it was found in six collateral observations that this was the only physical condition which presented a relation so as to throw the experiments into an orderly position.* By Table S we see that the respiratory power varies in different classes. The "gentlemen," for instance, are below most of the other classes: at the height of 5 feet 8 inches, they elevate by inspiration 2·35 inches of mercury. This may account for the fact why Dr. Hales could only raise 2 inches of mercury by this effort.

The expiratory power is normally more irregular — more apt to vary — than the inspiratory power. The expiratory muscles participate in other duties besides that of mere expiration; the vocation of the glass-blower, the trumpeter, the wrestler, the jeweller (blow-pipe), and the sailor, especially call these muscles into use, increasing their natural power. They thus oftentimes become excessively strong. The inspiratory muscles are exclusively for supplying us with air, in which act they have only to oppose the uniform resistance of elasticity. The *inspiratory* power is therefore the best indication of the "*health*"— the "*vis vitæ*."

As an instance of the effect of vocation changing one of the respiratory powers and not the other, we may notice the Metropolitan police and the Thames police. The *inspiratory* power of these two classes is nearly equal, whilst the *expiratory* power of the Thames police exceeds that of the Metropolitan police,—the former using their upper extremities, whilst the latter use their lower extremities most: — the former chase the thief by the use of the oar; the latter by the swiftness of their legs.

Compositors and pressmen stand low the former are the *lowest* in their respiratory power; the pressmen are much higher. The order in which some of these classes come is as follows: — the most powerful are the Thames police; next, the sailors; the paupers and the gentlemen are nearly equal; and lastly, diseased cases. The two last lines is the mean of the four healthiest classes, — the seamen, firemen, Thames police, and pugilists: their maximum is 3 inches; the mean of the whole classes together is little more than 2½ inches. The measure of this power when expressed by inches of mercury appears small, yet, when hydrostatically considered, it is very great. Men have wondered that they could not elevate more mercury in the tube; but all surprise vanishes when it is recollected, that, by the law of hydrostatics, when a column of 3 inches height of mer-

* For the other observations, see p. 1068, and Med. Chir. Trans. 1846. Vol. 39. p. 143 et seq.

TABLE S. — Inspiratory and Expiratory Power in relation to the Stature.

	Class.	0 to 5 ft.			5 0 to 5 1			5 1 to 5 2			5 2 to 5 3			5 3 to 5 4			5 4 to 5 5			5 5 to 5 6		
		Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.
Seamen ...	A.	3·17	3·44	5	2·20	2·60	1	2·03	3·48	7	2·40	3·74	1	2·48	3·89	9	2·68	4·23	8	2·84	4·25	15
Firemen ...	B.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Metropolitan police...	C.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Thames police	D.	2·55	3·28	1	...	...	...	...	...	...	...	...	...	2·70	4·26	6	3·05	4·50	9	2·58	4·34	9
Mixed class	E.	3·00	3·74	1	2·00	3·36	1	2·52	3·25	5	2·31	3·15	5	1·85	2·69	17	2·30	3·05	18	2·40	3·37	16
Grenadier guards.......	F.	...	...	...	...	...	...	...	...	...	4·50	5·36	1	...	...	...	4·50	3·10	1	2·70	2·90	2
Pugilists ...	G.	...	...	...	...	...	...	3·80	4·75	1	2·40	2·41	2	3·50	3·74	1	3·53	5.29	3	3·86	4·75	3
Draymen...	H.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1·30	1·70	1
Horse guards	I.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Paupers ...	K.	1·79	2·45	7	1·46	1.93	3	2·52	2·96	9	2·09	3·30	10	2·30	3·38	21	2·17	3·30	20	1·93	3·13	19
Compositors	L.	...	...	...	...	...	...	2·32	2·96	3	1·65	2·52	1	2·13	3·23	5	2·17	2·91	4	1·65	2·85	7
Pressmen	M.	...	...	...	2·20	5·00	1	...	...	...	3·35	4·20	1	...	...	...	2·81	4·17	3	2·04	3·27	8
Mean of printers ...	N.	...	...	...	2·20	5·00	1	2·32	2·96	3	2·50	3·36	2	2·13	3·23	5	2·49	3·54	7	1·84	3·06	15
Diseased cases.	O.	0·82	1·37	5	1·30	3·00	1	1·16	2·14	4	1·00	1·81	4	1·34	2·30	...	0·74	1·00	1	1·25	1·52	9
Gentlemen.	P.	...	...	...	...	...	...	1·50	2·80	1	2·55	3·00	1	1·77	2·92	6	2·01	2·10	7	1·94	3·21	11
Mean of the four healthiest classes	Q.	2·55	3·28	1	...	...	...	...	...	...	...	...	...	2·70	4·32	8	2·84	4·33	12	2·70	3·87	29
Mean of all the 13 classes except the diseased ...	R.	2·42	2·95	14	1·80	2·79	6	2·41	3·19	25	2·33	3·36	21	2·21	3·32	67	2·48	3·51	76	2·40	3·58	110

	Class.	5 6 to 5 7			5 7 to 5 8			5 8 to 5 9			5 9 to 5 10			5 10 to 5 11			5 11 to 6 0			6 0 to 6 +		
		Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.
Seamen ...	A.	2·63	3·56	15	2·87	4·15	14	3·11	4·19	9	2·66	3·84	18	2·41	3·86	12	2·61	4·15	6	2·00	4·00	1
Firemen ...	B.	3·17	3·95	15	3·02	4·09	15	3·08	4·50	18	2·69	3·33	5	2·40	3·74	1	3·65	6·81	2	2·10	2·80	1
Metropolitan police...	C.	3·07	4·05	4	2·89	4·07	39	2·81	4·10	46	2·92	4·00	23	2·78	3·41	12	2·33	3·23	12	2·75	3·77	8
Thames police	D.	2·97	4·44	16	3·08	4·31	16	3·05	4·66	11	2·54	4·27	5	2·78	4·45	3	...	...	...	...	...	...
Mixed class	E.	2·31	3·38	21	2·16	3·17	27	2·46	3·50	17	2·41	3·67	15	2·07	2·45	7	2·14	3·08	11	2·77	4·10	2
Grenadier guards.......	F.	...	...	...	2·68	3·83	8	2·94	3·89	19	2·23	3·49	18	2·56	3·76	11	1·92	3·17	12	2·46	3·82	14
Pugilists ...	G.	4·20	6·42	2	3·65	4·61	2	3·70	4·84	1	3·78	4·38	2	3·77	4·89	4	3·25	4·93	2	3·52	4·64	2
Draymen...	H.	2·80	3·55	1	2·73	4·59	3	2·37	4·16	3	4·50	5·43	3	3·21	4·30	6	2·02	3·13	2	3·15	5·00	1
Horse guards	I.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·71	4.84	31	2·68	4·66	27
Paupers ...	K.	2·45	3·33	10	1·96	2·71	8	1·87	3·33	9	2·55	3·46	1	1·47	1·67	2	1·61	3·70	4	...	...	...
Compositors	L.	2·05	3·10	5	2·43	3·22	7	2·83	3·41	8	2·00	2·39	2	...	...	...	1·50	1·91	1	...	...	...
Pressmen	M.	2·10	2·95	3	2·62	2·58	8	1·65	2·05	1	2·95	3·93	3	2·62	3·72	2	...	...	...	...	...	...
Mean of printers ...	N.	2·07	3·02	8	2·52	3·40	15	2·24	2·73	9	2·47	3·16	5	2·62	3·72	2	1·50	1·91	1	...	...	...
Diseased cases.	O.	0·79	1·70	4	1·67	1·88	7	1·32	1·78	8	0·93	1·60	3	0·88	1·59	3	0·40	2·25	1	1·65	4·02	1
Gentlemen.	P.	2·35	2·62	12	2·35	3·30	16	2·40	3·30	16	2·74	3·59	7	2·84	3·49	12	3·12	4·94	5	2·38	3·70	4
Mean of the four healthiest classes	Q.	3·07	4·18	35	2·96	4·13	70	2·91	4·28	75	2·83	8·94	33	2·77	3·63	16	2·65	4·48	45	2·67	4·41	36
Mean of all the 13 classes except the diseased ...	R.	2·65	3·65	104	2·65	3·76	163	2·75	3·94	158	2·65	3·79	102	2·67	3·62	72	2·51	4·11	85	2·65	4·17	58

cury is sustained, the force exerted by the diaphragm alone is equal to the weight of as much mercury as it would take to cover a space of the same area as the diaphragm, three inches deep. The column of mercury raised, therefore, will not safely serve to compare the respiratory power of men of *different* dimensions, for the area of the thorax must also be considered. For instance, we examined a man, 4 feet $7\frac{1}{2}$ inches high (circumference of the chest 29 inches), who raised 3·15 inches; and another man, 7 feet high (chest 50 inches in circumference), who could only elevate 3 inches of mercury: but the dissimilarity between the area of the diaphragm in the dwarf and giant was such, that the latter in reality lifted about 500 lbs., and the former only about 39 lbs. Suppose the base of his chest to be 57 superficial square inches; had this man raised 3 inches of mercury by his inspiratory muscles, his diaphragm alone must have opposed a resistance equal to more than 23 oz. on every inch of that muscle, and a total weight of more than 83 lbs. Moreover, the sides of the chest, by attenuating the air within, resist an atmospheric pressure equal to the weight of a covering of mercury 3 inches in thickness, or more than 23 oz. upon every inch surface, which, if we take at 318 square inches, the chest would be found to resist a pressure of 713 lbs.; and, allowing the elastic resistance of the ribs as $1\frac{1}{2}$ inch of mercury, this will bring the weight resisted by the *inspiratory* muscles of the thorax as follows: —

Diaphragm - - - -	83 lbs.
Walls of the chest - -	731 „
Costal resistance (elastic) -	232 „
Lung - - - -	100 „
	1146 lbs.

Or, in round numbers, we may say, that the inspiratory muscles of such a man of ordinary dimensions resisted 1000 lbs. This is a resistance *not* counterbalanced; for were it counterbalanced, it would only be mere displacement. We have made a safe addition for the elasticity of the lungs. We think it may be confidently stated that nine-tenths of the thoracic surface conspire to this act, allowing the remainder to lie dormant.

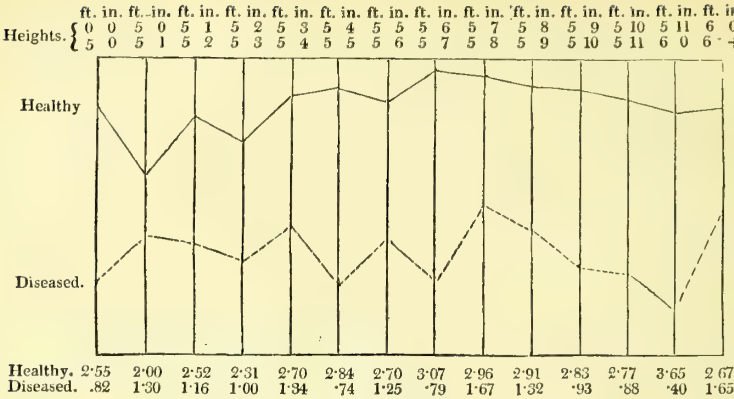
Although the difference between the inspiratory and expiratory powers, when tested to their utmost, is so great, yet it must not be thought that these two powers are in their ordinary action so dissimilar; and indeed, when all things are considered, the question may still be asked, is the inspiratory or expiratory act the strongest? In the last table (Table S.) there is uniformly a difference, because the two powers are unequally taxed with resistance. All elastic force is co-operating with the *expiratory* power, whilst it antagonises the *inspiratory* power; therefore all the power manifested in *inspiration* is muscular; but in *expiration* it is partly muscular and partly elastic power. This probably causes the great apparent difference between inspiration and expiration; at least, if we separate the resistance we assign to the elasticity of the ribs and lungs from the expiratory power, we shall nearly equalise the two. This can be easily proved upon one's own person: — partially empty the chest of air; then forcibly test your expiration upon the hæmadynamometer: probably you can only elevate the mercury $1\frac{1}{2}$ inch; then inspire deeply, completely filling the lungs, and now test your expiratory power, — instead of $1\frac{1}{2}$ inch, it will probably be 5 inches. This difference appears due to two causes. 1st. In the *deep inspiration* the ribs are put more upon the stretch than in the *moderate* inspiration. 2d. The chest, when distended with air, presents points of attachment for muscular traction, to a greater mechanical advantage.

The most remarkable respiratory power, as tested by the hæmadynamometer, was in the case of a Chatham recruit, who was frequently examined by Dr. Andrew Smith, on whose accuracy we place implicit confidence. The man's age was 18; height, 5 feet 6 inches, weight, 10 stones 5 lbs.; circumference of his chest, 35 inches; vital capacity, 230; — his inspiratory power was equal to 7 inches of mercury, and his expiratory power to 9 inches! The thoracic power of this man, according to our last calculation, was equal to a gross weight of 2200 lbs. This was the amount *manifested*, and we may safely consider 50 per cent. of muscular power to be lost by the obliquity of the respiratory muscles; so that this man *possessed* a vital power equal to nearly 2 tons! He exhibited in no other respect any remarkable feature of strength.

A dynamic instrument like the hæmadynamometer would be useful to those whose duty it is to examine men for certain public services, as for the army, navy, police, fire-brigade, &c. With care, it would often detect disease. The efforts required to move the mercury test the whole trunk of the body. The *inspiratory test* produces a rarefaction of the air within the thorax, causing an extra (unbalanced) atmospheric pressure upon the body from without. In this way we have detected rupture of the membrana tympani; for the air rushing in by this opening equalised the difference otherwise produced. The *expiratory test* is of a contrary order, increasing the pressure from within; in this way we have detected hernia.

The difference between the healthy and diseased respiratory powers is broadly marked.— It is shown in the annexed diagram (*fig.* 702.); the lower curve is the power manifested by diseased, and the upper curve that of healthy persons. The difference is about 50 per cent., because weakness is the most prominent symptom of disease. We do not compare the expiratory power for the reason already assigned. We affix at the bottom of the diagram the relative powers in figures.

Fig. 702.



Inspiratory power of the healthy and diseased compared.

Of the Respiratory Volumes. — For 1500 years, from the time of Galen to Robert Boyle, naturalists, physicians, and philosophers disputed the simple operation of drawing air into the thorax. There were three explanations given :—*First*, " That by the dilatations of the chest the contiguous air is thrust away, and that, pressing upon the next air to it, and so onwards, the propulsion is continued till the air be driven into the lungs, and so dilate them."

Secondly, That the chest is like a pair of common bellows, " which comes therefore to be filled because it was dilated."

Thirdly, That the lungs are like a bladder " which is therefore dilated because it is filled."

The great philosopher Boyle adopts the bellows' action viz., that the lungs are filled with air, because the chest is dilated, and that without the motions of the thorax they could not be filled. " Indeed," says Boyle, " the diaphragm forms the principal instrument of ordinary and gentle respiration, although to restrained respiration, if I may so call it, the intercostal muscles, and perhaps some others, may be allowed eminently to concur." * Cotemporary with Boyle, we find Richard Lower † (1667) correctly understanding the respiratory action; he makes a dog breathe like a broken-winded horse, by dividing the phrenic nerve. What Boyle and Lower demonstrated, every one now believes without dispute; yet it took 100 years' disputation, through a number of unfounded hypothetical and contradictory speculations, before the truths which Boyle and Lower promulgated were received. As late as the eighteenth century, little more than one hundred years ago (A. D. 1737), it was stated in the Gulstonian Lectures before the Royal College of Physicians that there was air between the pleuræ ‡,—a condition which we now know is almost instant death. The first great epoch in the history of respiration was at the time of Harvey (1628), when he published his first work on the circulation of the blood, though at this time he did not stand commended for his discovery ; for most persons opposed it ; others said it was old ; and the epithet " *circulator*," in its Latin invidious signification, was applied to him. We know respiration depends upon the weight of the air; and at a very remote period air was known to possess the quality of weight. Aristotle and other ancient philosophers expressly speak of the weight of the air. The process of respiration is attributed by an ancient writer to the pressure of the atmosphere forcing air into the lungs.* Galileo was therefore fully aware that the atmosphere possessed this property ; yet when his attention was so immediately directed to one of the most striking effects of it, he did not see its connection with respiration. It was reserved for his pupil, Torricelli, to discover (1643) the true law of atmospheric pressure ; and as we can find no philosophical reason assigned, prior to this date, why air enters the lungs in inspiration, we may date this as a first step in the advance of knowledge upon our subject. Nevertheless, no less an authority than Swammerdam adopted, for upwards of twenty years after this, the unphilosophical reasoning of Descartes, that the air was forced into the lungs by its increased density around the breast, occasioned by the dilatations of the thorax, in consequence of the elevation of the ribs.

In 1667 some attention was paid to respiration being maintained by distinct volumes of air ; for Hook kept a dog alive with common bellows by artificial respiration. † Fabricius, in the beginning of the 17th century, correctly explained the action of the diaphragm. ‡ Borelli is the earliest physiologist (1679) who

* Boyle's Life and Works, fol., Lond. 1744, vol. i. p. 64.

† Phil. Tr. Abr., vol. i. p. 179.

‡ Hoadly, Lec. on Resp., 4to, 1740, Lond., p. 11, et seq.

* Lardner's Cyclop. Nat. Phil. Hydr. and Pneum. p. 247.

† Phil. Tr. Abr. vol. i. p. 194.

‡ De Resp. ii. c. viii.

established an experimental inquiry into the *quantity of air* received by a single inspiration.* Jurin improves upon Borelli. About this time (1708) Dr. James Keile made some correct measurements of the volume of air breathed.† Then followed Dr. Hales, who threw more light upon the doctrine of air, the power of respiration, and the power of the heart, than all his predecessors; yet he was quite ignorant of the use of respiration; and at this period (1733) really very little was known upon the subject. In 1757 and following years, Black, Rutherford, Lavoisier, Priestley, and Scheele, the chemists of the age, threw light upon the matter by discovering the composition of the atmosphere, and consequently the composition of respired air. It is since the time of Black that the most valuable mass of our knowledge upon respiration has been discovered.

The functions of the thorax may be divided into two great heads, — the chemical and the physical; for an account of the former see RESPIRATION.

Every point of the thorax can move for the purpose of respiration; and hence has followed a division of these movements, nominated after the parts which respectively carry on their functions, viz. costal breathing, and abdominal or diaphragmic breathing. These motions are, in health, symmetrical, constant, regular, sensitive, and precisely the same; otherwise disease must exist.

The breathing movements are also expressive of mental emotions. The tragedian imitates them to give force to the character he represents, whether it be the *stealthy breathing* of the Roman conspirator sharpening his knife, or the deep *swelling inspiration* of Ajax defying the lightning; these representations, without such movements, would be but dull pictures of the mind of the authors who left such characters on record. It is much easier to become delicately familiar with these movements and their characteristic differences, than it is to describe them.

The latitude of movement, performed by the walls and floor of the thorax, admits of three common degrees of division: —

First, extreme expansion or enlargement.

Second, extreme contraction or diminution; and

Third, an intermediate condition, — an ordinary or quiescent state.

These three divisions necessarily displace volumes of air of different magnitude.

Were the respiratory movements but two in number, extreme expansion and extreme contraction, the quantity of air moved, and the character of the movement, would be easy of calculation and expression; but the intermediate breathing or quiescent movement being so limited, so perfectly under the control of the will, so readily affected by mental emotions and by the animal functions, renders the calculation of the volume of air ordinarily passing through the lungs a very difficult question.

The quantity of air in the thorax, together with those portions which can be added at will, may be arranged and denominated thus: —

First, residual air.

Second, reserve air.

Third, breathing air.

Fourth, complemental air.

Fifth, vital capacity.

1st. *Of residual air.* — After death the lungs contain air, which is not displaced by the last expiration; this quantity remains in the thorax as long as the lungs maintain their natural structure; therefore we have no control over this volume of air: to it we assign the term "*residual air.*"

2nd. *Reserve air* is that portion which remains in the chest after the gentle ordinary expiration, but which may be displaced at will.

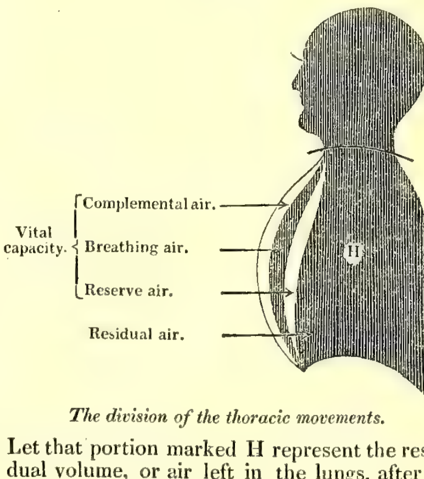
3rd. *Breathing air* is that volume which is displaced by the constant gentle inspiration and expiration.

4th. *The complemental air* is that volume which can *at will* be drawn into the lungs by a violent exertion above the moderate effort of ordinary breathing, constituting the deepest possible inspiration. It is only occasionally demanded.

5th. *The vital capacity* is these last three divisions combined, being the greatest voluntary expiration, following the deepest inspiration.*

This division of thoracic movements for commanding these different volumes of air may be more clearly illustrated by diagram 703.

Fig. 703.



The division of the thoracic movements.

Let that portion marked H represent the residual volume, or air left in the lungs, after a complete voluntary expiration; the part next

* De Motu Animalium, p. 2. prop 81.

† Tentam. Med. Phys. p. 80.

* According to physiological nomenclature, perhaps the term "*vital capacity*" may be objectionable; but we adopt it, for want of a better term, to signify a capacity or volume of air which can *only* be displaced by *living movements*, and may therefore be termed a "living volume," or "vital capacity."

anteriorly, left white, — the reserve volume, or latitude of movement appropriated for displacing that air left in the lungs at the end of an ordinary expiration; the black stripe next anteriorly represents the mobility for commanding the volume of breathing air; and lastly, beyond this another white stripe shows the extreme limit of inspiration or thoracic mobility commanding the complemental volume of air. These last three — viz. the complemental, breathing, and reserve volumes conjointly — we style *vital capacity*. The absolute capacity may be considered as *all* the divisions combined in one.

Whatever limits the mobility of the thorax must modify the volume of air respired. This applies to any or all of the above movements. Therefore the measure of the volume of air displaced becomes a measure of the thoracic mobility; and as disease affects the mobility of the chest, the measure of the volume of respired air becomes a measure of disease.

The *residual volume* is entirely independent of the will, and always present in the chest. The *reserve volume*, to use a simile, is a "tenant at will." The *breathing volume* is constantly passing out and in, many times a minute. The *complemental volume* is seldom in the chest, and then only for a very brief period.

Whatever be the breathing volume necessary for our well-being, the mobility demanded to maintain it is an intermediate mobility, just as the dark stripe in *fig.* 703. is intermediate between the white stripes; so that at both ends of the ordinary breathing mobility there exists a spare mobility, which we can command into action according to the necessities required. This reserve and complemental mobility may be looked upon as a broad, spare margin which encompasses our breathing; so that any sudden exertion may not (as it otherwise would) produce painful dyspnœa and premature death.

This spare mobility, therefore, is always ready to admit of irregularities in the ordinary breathing, such as frequent or infrequent, quick or slow, regular or irregular, great or small, equal or unequal, easy or difficult, complete or incomplete, long or short, abdominal or costal; as in coughing, running, laughing, crying, singing, sighing, and vociferating, many of which are but extensions or modifications of the *ordinary* mobility, infringing upon this margin — the complemental or reserved mobility.

This spare mobility is not only ready for such exigencies as above mentioned, but it becomes a reservoir for "times of need." Thus a man can take from 230 to 300 cubic inches of fresh air into his lungs, and live upon it without inconvenience for *two minutes* without breathing.* The knowledge of this fact would be of much use towards rescuing a fellow creature from suffering amidst dense smoke or in an irrespirable atmosphere, as is found sometimes in mines and wells. A variation of this condition was once witnessed when Mr. Brunel descended to examine the breach which the river had made in the Thames Tunnel. Having lowered the diving-bell nearly 30 feet to the mouth of the opening, this was found too narrow to admit the bell; so that no further observation could be made upon the workings, which were about 8 feet or 10 feet deeper: Mr. Brunel, therefore, laying hold of a rope, left the bell, and dived himself down the opening. His companions in the bell, being alarmed at the length of his stay, now about *two minutes*, gave the signal for pulling up; and the diver, unprepared for the signal, had hardly time to catch the rope, which he had let go, and was surprised to find, on coming into the bell, that he had remained below so long. On descending again, he found that he could with ease remain *fully two minutes* under water. In this case the atmosphere, under a pressure of 30 feet of water, charged the lungs with nearly a double volume of air compressed into the same bulk as one volume at the surface of the water. Our ordinary breathing volume can only supply us for from three to five seconds; for if we suddenly stop breathing for that time, we experience a degree of inconvenience.

Of the volumes of air expelled from the lungs. — A knowledge of this is of incalculable value to the physician and to the surgeon; for disease cannot attack the lungs or the thoracic boundaries, without diminishing the respiratory volume, which change ultimately leads to the variations of the respiratory murmurs, first noticed as a diagnostic sign of disease by Laennec. Many experimenters have measured the different volumes of respired air, not primarily in reference to disease, but merely as collateral to the observations of the chemist: hence experiments have been few, and deductions highly discrepant.

(*a*) *Residual volume.*—Dr. Hales notices this volume, but assigns no measure for it*; Allen and Pepys estimate it at 108 cubic inches in stout men of 5 feet 10 inches†; Davy at 41 cubic inches‡; Goodwyn, by the mean of seven experiments, at 108 cubic inches; Kite, who writes expressly upon submersion, is obscure upon this point§; Dr. Bostock allows 120 cubic inches‖; Dunglison gives Menzie's estimate of 179 cubic inches; Jurin estimates it at 220 cubic inches; Fontana at 40; and Cuvier at from

* It is better to inspire and expire forcibly five or six times, cleansing the lungs of the old air, and then give one deep inspiration, and there hold. For the first 15 seconds a giddiness will be experienced; but when this leaves us, we feel not the slightest inconvenience for want of air; and two minutes of time can be passed through without breathing. The most expert pearl-divers cannot remain under water for a longer time.

* Stat., vol. i., p. 239.

† Phil. Tr., 1809., vol. xcix. pp. 404. 428.

‡ Chem. and Phil. Remarks, p. 410.

§ Essays and Obs. Physical and Med. 1795, p. 8.

‖ E. Phys. 3d. Ed. p. 318.

100 to 60; Mechli at 52 and 40*; Dr. Herbert, of Gottingen concludes this volume to be "very little."† We have found it to vary from 75 to 100 cubic inches. It must be relative to the absolute capacity of the chest, which varies from 248 to 457 cubic inches. The mean absolute capacity is 312 cubic inches. Allowing 100 cubic inches for the heart and large blood vessels, and 100 cubic inches for the parenchymatic structure of the lungs, will leave a little more than 100 cubic inches for the residual air; therefore Allen and Pepys's opinion may be relied upon as very near the truth.

(*b*) *Reserve volume.* — Goodwyn omits this volume altogether; and this omission was pointed out forty years ago by a physiologist who himself omitted any notice of the *complemental* air. Kite estimates this at 87 cubic inches; Davy, by an experiment upon himself, at 77 cubic inches‡; Dr. Bostock, from trials upon himself, at 160 or 170§; Mechel at 110 cubic inches.|| It averages about 100 cubic inches; our observations range from 70 to 110 cubic inches. It is regulated by the point at which the ordinary breathing movement commences.

(*c*) *Breathing volume.* — This has attracted most attention; but the discrepancies of opinion are nearly commensurate with the number of observations. It would require years of labour to determine this volume by direct experiment, in a manner to be available to the physician; and it would require a long time to perfect the observation of it upon a single patient, because these movements are so delicately affected by the mind, so perfectly uncontrollable, and the volume is so small, that a little error would seriously damage the value of the observation. The volume assigned by observers, varying from 3 to 100 cubic inches, is as follows:—

	Cub. in.
Abildgaard	3
Abernethy	12
Keutsch	6 to 12
Goodwyn	3 and 14
Lavoisier and Seguin	13
Wurzer and Lametheria	8 or 10
Kite	17
Davy	13 and 17
Allen and Pepys	16·5
Herbst	16 to 25
Jurin	20
Borelli	15 to 40
Herdolt	25 to 29
Dalton	30
Fontana	35
Richeraud, Foland, Gordon, and Cavallo	30 to 40
Hales, Jurin, Sauvages, Haller, Ellis, Sömmering, Thomson, Sprengel, Bostock, Chaptal, Bell, Monro, and Blumenbach	40
Menzies	42 to 46
Reil	40 to 100

upon an average, it varies from 16 to 20, though we have occasionally found it vary from 7 to 77 cubic inches. Though our observations upon this point are but scanty compared with those we made on the vital capacity, yet from about 80 experiments we conclude that man in a perfectly quiet state, as when sitting, reading, &c., breathes much less than he does under the ordinary excitement of moving about. We think the perfectly quiet breathing, when we can scarcely perceive any movement (which is by no means uncommon), may be from 7 to 12 cubic inches, and when under ordinary excitement and exercise, from 16 to 20 cubic inches; we have known it in one case as high as 77 cubic inches. It is probable that the quantity is relative to the volume of blood to be aërated. Herbert found that adults of smaller stature breathed less than those who were taller.* It is probable that phthisical patients breathe very little, — from 2 to 4 cubic inches; but the number of their breathing movements is greater, which compensates for this small quantity.

(*d*) *Complemental volume.* — Davy, from a single experiment (upon himself), calculates this at 119 cubic inches†; Kite, at nearly 200 cubic inches.‡ It is regulated by the position of the ordinary breathing movement, which is intermediate between it and the reserve air. It averages, from direct experiment, rather higher than the reserve volume, — about 105 or 110 cubic inches. Taking the mean height at 5 ft. 8 in. the vital capacity is 230 cubic inches, that is to say —

	cub. in.
Reserve air	100
Ordinary breathing	20
Complemental	110
	230

(*e*) *Vital capacity volume.* — Jurin and Hales correspond in stating this at 220 cubic inches§; Davy at 213 cubic inches||; and he remarks in a note, "this capacity is probably below the medium. My chest is narrow, measuring in circumference but 29 inches, and my neck rather long and slender." It is probable the figures 29 are a misprint for 2 feet 9 inches round the chest. Dr. Thomson, from the mean of twelve experiments, upon men from fourteen to thirty-three years of age, states it at 186½ cubic inches. Dr. Thomson himself could expel 193 cubic inches. He mentions that this volume is constant when once determined.

* Mechli's Manual Descrip. and Pathological Anat., vol. ii. p. 448.
† Bostock, Op. Cit., p. 316; and Archives Gén. de Méd., t. xxi. p. 412. et seq.
‡ Op. Cit., pp. 47, 48.
§ Op. Cit. p. 316.
|| Manual of Descrip. Anat., vol. ii. p. 447.

* Müller, El. Phys., 1st ed. 8vo., Lond. p. 294, vol. i., 1847.
† Op. Cit. p. 410.
‡ Op. Cit. p. 47.
§ Hales's Sat., 1732, vol. i. p. 239.
|| Op. Cit. p. 410.

The temperature of the respired air is not mentioned.* Goodwyn states it at 200 cubic inches†; Kite, at 300 cubic inches‡; Menzies at 200 §; Bostock‖, corroborated by Dunglison¶, omitting the complemental volume, at 210 cubic inches; lastly, Thackral, who takes this volume as the measure of health; examines some soldiers, who give the mean of 217 cubic inches, and some shoemakers, who average 182 cubic inches; and he remarks, "a tall young cornet threw out 295 cubic inches; this was the greatest quantity I ever witnessed."**

According to this evidence, the respective volumes are, —

		Cub. in.
Residual	volume, from	40 to 260
Reserve	,, ,,	77 ,, 170
Breathing	,, ,,	3 ,, 100
Complemental	,, ,,	119 ,, 200
Vital Capacity	,, ,,	100 ,, 300

The apparent discrepancies of the breathing volumes are entirely due to the want of collateral observations; for there is no distinction between the sexes, nor age, nor stature, nor weight. We have determined the vital capacity in one man as 80 cubic inches, in another 464 cubic inches; therefore we might say this volume varies from 80 to 460 cubic inches; but this discrepancy is cleared up, when we add that the height of the former was 3 feet 9 inches, and his weight 4 stone 9 lbs., while the latter measured 7 feet, with a weight of 22 stone; and that if we arithmetically reduce the one to the other, the vital capacity of a dwarf is within half an inch of what it actually was, viz. 79·56 cubic inches by calculation, and 80 cubic inches by direct experiment. Collateral observations clear up the experiment; thus Kite was probably a *tall* man, and *therefore* he states the vital capacity as 300 cubic inches; Davy at 213 cubic inches, because he was of shorter stature, probably about 5 feet 7 inches; Hales, Jurin, and Goodwyn about 5 feet 8 inches. We come to this conclusion, because we find this volume bear a strict relation to stature. Therefore, probably, all the observations already mentioned are correct, and only wanted another combination to remove the apparent discrepancies.

We have especially directed our attention to one of these volumes of air, the *vital capacity*.

Vital Capacity. — There are two ways of measuring the permeability of the lungs, or the volumes of air which they can displace, viz. by measuring the actual movement or mobility of the thoracic boundaries, or by directly measuring the absolute cubic inches of the volume of air expired. The former is open to an error, but the latter is not.

* Thomson's Anim. Chem., 1843, p. 610. et seq.
† Op. Cit. p. 32. *note.*
‡ Op. Cit. p. 48.
§ Mayo's Outlines of Phys., p. 76.
‖ Op. Cit. p. 321,
¶ Ibid. vol. ii. p. 91.
** Thackral on the Effects of Arts, Trades, &c. upon Health, p. 21. et seq.

If we take the movement as an index to the permeability of the lungs, we obtain an evidence only of movement, and not of the permeability of the lungs for air, for we may move the thoracic boundaries, and yet *not breathe*. But when we measure the volume of air, it is self-evident that this must be the measure of both the permeability of the lungs and of mobility of the thoracic boundaries, because we cannot breathe without moving. The classes of persons we examined were as follow: —

	No.
Sailors (Merchant Service)	121
Fire Brigade of London	82
Metropolitan Police	144
Thames Police	76
Paupers	129
Mixed Class (Artisans)	370
First Battalion Grenadier Guards	87
Royal Horse Guards (Blue)	59
Chatham Recruits	185
Woolwich Marines	573
Pugilists and Wrestlers	24
Giants and Dwarfs	4
Printers { Pressmen 30, Compositors 43 }	73
Draymen	20
Girls	26
Gentlemen	97
Diseased Cases	360
Total	2430

Each individual was subjected to the following observations: —

1st. The number of cubic inches given by the deepest expiration, following the deepest inspiration. This was taken three times, and the highest observation was noticed.

2nd. The *inspiratory* power.

3rd. The *expiratory* power.

4th. Circumference of the chest over the nipples.

5th. Mobility of the chest with a tape-measure.

6th. The height.

7th. The weight.

8th. The pulse (sitting).

9th. The number of ordinary respirations per minute (sitting).

10th. The age

11th. Temperature of the air expired.

To determine these points, we constructed an air receiver, denominated "Spirometer." We used a bent tube (hæmadynamometer) for ascertaining the respiratory power, scales and stand for the height and weight, and a common tape-measure for measuring the mobility of the chest.

We rarely exceeded three consecutive observations with the spirometer, because after this the volume of respired air diminishes from mere fatigue.

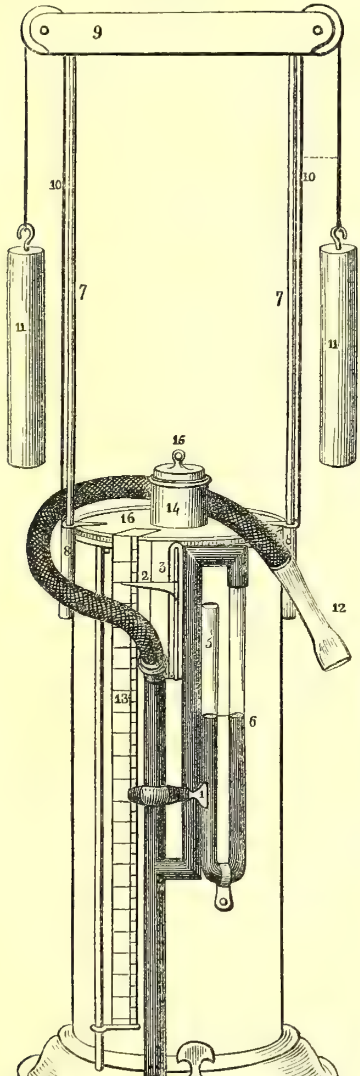
To measure the vital capacity volume. — The Spirometer (*fig.* 704.), consists of a vessel containing water, out of which a receiver is raised by breathing into it through a tube ; the height to which the receiver is raised, indicates the volume of the vital capacity.

To Prepare the Spirometer for Use :—

1st. Place the spirometer about three feet from the ground, upon a firm, level table.

2nd. Turn off the water-tap 4, and open the air-tap 1.

Fig. 704.



Spirometer.

3rd. Pour into the spout, behind, clear cold water, until it is seen to rise behind the slip of glass 3 (above the air-tube).

4th. Slide the moveable index 2, opposite 0 on the graduated scale 13, and add more water until it is exactly on a level with the straight edge of this index ; if too much water be poured in, draw off, by the tap 4, sufficient to bring the water down to the edge of the index.

5th. Pour a little coloured spirit into the bent tube 5, until it stands about $3\frac{1}{2}$ inches, as at 6.

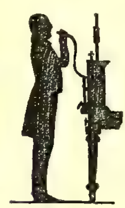
6th. Turn off the air-tap 1, then suspend the counterbalance weights, 11, 11, from the cord over the pullies.

The spirometer is now ready for an observation. The flexible tube, terminated with a glass mouth-piece, is held by the person about to be examined, and the tap 1 is to be kept open by the operator while the deep expiration is being made.

To discharge the air out of the receiver.— It will be seen that if the tap 1 be opened, the receiver will rise out of the reservoir by the power of the counterbalance weights, until it touches the cross-head 9. To return the receiver into its original position, the contained air must be discharged ; this can be done by slowly depressing the receiver down into the reservoir, and so pressing the air out by the way it entered,—through the air-tube. But, in order to do so more rapidly, a large valve at 14 admits of an instantaneous escape of the air. Therefore, to discharge the air, remove the plug 15 out of the socket 14 with one hand, while the other returns the receiver into its original position.

Let the person to be examined loose his vest, and any other tight garment — for the least pressure from dress affects the mobility — stand *perfectly erect* (*fig.* 705.), with the head

Fig. 705.



thrown well back ; then *slowly* and *effectually* fill his chest with air, or *inspire* as deeply as *possible*, and then he must lift the mouth-piece of the spirometer 12 to his lips, still standing in the same erect position, and place the glass mouth-piece between the lips, holding it there sufficiently tight so as not to allow any breath to escape, he then *slowly* makes the deepest *expiration*, displacing all the air he can out of his lungs through the mouth-piece into the spirometer, where it is measured to cubic inches, and confined there by a stop-cock, until examined. This observation should be taken three times. The operator, while the experiment is going on should place his left hand upon the shoulder of the person being examined ; in this way he can determine as to the perfect inflation of the lungs and expulsion of air from them as well as the character of the thoracic expansion. The thumb of the operator should cross the clavicle, while the fingers rest on the upper edge of the scapula, then he feels the expanding effect of inspiration, the swelling up of the apex of the thorax.

To determine the volume of air in the spirometer. — The graduated scale 13 is attached to the receiver, and made to extend downwards on the outside of the reservoir, so as always to be in relation with the index 2. On this scale 0 corresponds with the top of the receiver, or rather with the highest point to which the water can be made to rise within it. The number of cubic inches is shown by the degree upon the scale pointed to by the index 2, which corresponds with the level of the water in the receiver. But the water in the reservoir seen behind the slip of glass may not be level with the water within the receiver, just as the level of the water in a pneumatic trough may be higher or lower than the level of the water contained in a glass receiver standing upon the shelf. To know when these are level, depress the receiver until the coloured fluid in one leg of the bent tube, or inverted syphon, 5, stands level with that in the other leg, as at 6; then the water contained in the receiver, and that external to it, are level to each other; and the air within the receiver is of the same density as that without.

Immediately the plug 15 is replaced, and the hands withdrawn from the receiver, the latter will be seen to ascend some half-inch, the water behind the slip of glass to fall, and the coloured fluid in the bent tube to be unequal. This is caused by the excess of weight in the counterbalance (11, 11,), which is what necessitates the observation of the coloured fluid in the bent tubes and the correction above directed. The scale is graduated to degrees, each of which measures *two cubic* inches.

To correct the respired volume for temperature. — The table of the vital capacity-volume is calculated at 60° Fahr. The temperature of a volume of air displaced out of the lungs into the spirometer is reduced at once to the temperature of the water in the spirometer. This, according to the season of the year, may be 50° or 80°. Now 330 cubic inches at 50° would occupy 337 cubic inches at 60°, and 330 at 80°, would be 317 at 60°. For eight months out of the year there needs no correction. But a correction is necessary, when a thermometer in the room stands much above or below 60°. We may estimate the change in the bulk of air as $\frac{1}{500}$ for every degree (Fahr.) of variation of temperature; thus if a man breathe, in winter, 295 cubic inches of air into the spirometer, when the thermometer in the room stands at 55°, being 5 degrees below 60°, then $\frac{5}{500} = 2{\cdot}95$, must be added to the 295 cubic inches, making 297·95, or, in round numbers, 298 cubic inches. On the other hand, if the vital capacity be determined at 215 cubic inches, when the thermometer stands at 72°, which is 12° *above* 60°, $\frac{12}{500} = 5$ must be deducted; making the corrected observation 210, instead of 215 cubic inches.

In the absence of the spirometer, the measure of the *mobility of* the ribs, by means of a common *tape measure* is of much value.* To measure the mobility of the thorax with a tape measure, pass the tape measure round the chest under the waistcoat, over the region of the nipples, request the person to inspire deeply, and note that circumference, then to expire deeply, and again note the circumference, the difference is what we term the mobility. This is a rough measurement, but of no little value in doubtful cases of chest disease. This difference, or mobility, in men of all statures should be about 3 inches, if it is found only 2½ inches the examination should be carried further; sometimes the mobility extends to 5½ inches, but this is excessively rare. As a general rule, when we find the mobility three inches, we find the vital capacity volume correspond with our table. Sometimes the mobility may be good, and the vital capacity bad, because, as we have already noticed, we may move the walls of the chest without breathing.

The vital capacity is a constant quantity; habit will not increase it. But this volume is disturbed directly, and modified by five circumstances:

1st, by height; 2nd, by position; 3rd, by weight; 4th, by age; 5th, by disease.

1st. *Of the effect of height.*

The vital capacity volume bears a striking relation to the *height* of the individual examined; so that, if we take a man's height, we can tell the volume of his vital capacity. We show this by a curve in *fig.* 710., as before; let the perpendicular lines represent the heights increasing inch by inch from the left towards the right; the single continuous line is the curve of the *vital capacity*, which gradually ascends as it passes over the perpendicular lines. The heights extend from 5 feet to 6 feet; above six feet the observations are few. Whether the vital capacity volume maintains the same regular progression beyond this point remains to be determined. If we draw a line in a perfect arithmetical ascent of eight units for every increasing height, the line of vital capacity will be observed to run nearly parallel with it; therefore this volume increases with the increase of stature. The figures at the bottom represent the vital capacity in cubic inches, being the mean of the observations under each height. The following table (Table T.) places the subject more in detail: —

A cursory inspection of the table shows that the vital capacity increases with the height; this is without any consideration as to age, weight, or circumference of the chest. For clearness, we arrange it in a more reduced form, as in Table U.

* Dr. Sibson and Dr. Quain have invented some ingenious instruments for measuring the thoracic movements externally.

TABLE T.—Mean Vital Capacity Volume, in relation to Stature, of Fifteen different Classes of Men, or 1923 Cases, considered healthy.

	0 to 5 ft.		5 ft. to 5 ft. 1 in.		5 ft. 1 in. to 5 ft. 2 in.		5 ft. 2 in. to 5 ft. 3 in.		5 ft. 3 in. to 5 ft. 4 in.		5 ft. 4 in. to 5 ft. 5 in.		5 ft. 5 in. to 5 ft. 6 in.		5 ft. 6 in. to 5 ft. 7 in.		5 ft. 7 in. to 5 ft. 8 in.		5 ft. 8 in. to 5 ft. 9 in.		5 ft. 9 in. to 5 ft. 10 in.		5 ft. 10 in. to 5 ft. 11 in.		5 ft. 11 in. to 6 ft.		6 ft. to 6 ft. +	
	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.
Seamen	151	5	206	1	192	7	219	1	218	10	213	9	217	15	226	14	229	15	239	11	258	18	273	12	270	6	246	2
Fire-brigade	...	...	...	...	...	...	...	...	210	1	208	2	218	20	215	17	231	26	231	20	237	3	260	1	249	2	...	...
Police, Metropolitan..................	...	...	...	...	...	...	...	...	...	...	...	...	...	...	234	4	228	33	226	46	248	22	234	13	262	12	281	11
Ditto, Thames	158	1	...	...	...	...	...	...	187	6	206	9	228	9	222	15	246	17	250	10	240	5	257	3	...	...	...	...
Paupers........................	151	7	166	3	162	10	180	10	174	21	191	20	189	19	210	10	187	9	199	10	262	1	240	3	...	...	...	...
Mixed class	80	1	185	1	162	5	181	5	185	17	191	16	192	20	210	20	222	28	238	16	246	14	238	7	269	9	...	...
Grenadier Guards........................	...	...	...	...	...	...	168	1	...	...	218	1	199	2	...	...	228	7	233	22	240	16	232	11	253	9	258	14
Compositors	...	...	...	...	176	3	165	2	196	5	188	6	208	7	227	5	215	8	214	6	231	3	...	...	253	1	...	...
Pressmen	...	...	152	1	...	...	...	...	...	...	213	2	203	8	204	3	223	7	245	1	239	4	247	2	...	...	...	...
Draymen	...	...	...	...	...	...	...	...	...	...	...	...	192	1	241	1	218	3	223	4	245	1	261	6	248	4	...	...
Gentlemen........................	...	...	...	...	145	1	161	1	156	7	177	9	189	14	208	10	208	18	208	16	236	8	254	12	250	5	262	5
Pugilists, &c........................	...	...	...	...	202	1	218	2	218	1	211	4	217	3	267	3	206	1	243	2	273	3	272	5	248	2	...	...
Horse Guards	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	255	30	275	26
Mean of first series	135	14	177	6	173	27	184	22	193	68	208	78	204	118	224	102	220	172	229	164	246	98	254	75	255	82	260	62
Chatham recruits	...	...	167	1	181	1	...	...	189	1	...	...	233	19	238	67	247	38	251	22	266	16	236	2	261	5	284	3
Woolwich marines	...	...	...	...	...	...	...	...	...	...	216	3	223	7	233	99	235	192	240	130	246	75	250	39	263	18	276	9
Miscellaneous	...	..	180	1	...	...	194	4	198	4	180	4	196	10	222	18	213	9	230	13	226	12	...	...	259	7	286	6
Total mean under each height......	135	14	175	8	177	28	189	26	193	73	201	85	214	154	229	286	228	411	237	329	246	201	247	116	259	112	276	80

Table U. — Progression of the Vital Capacity Volume, with the Stature — from the above.

Height.	Series from Observations on 1012 cases.	Series from Observations on 1923 cases.	Series in Arithmetical Progression.
	1st result.	2nd result.	
5 0 – 5 2 } 5 1	175·0	176·0	174·0
5 2 – 5 4 } 5 3	188·5	191·0	190·0
5 4 – 5 6 } 5 5	206·0	207·0	206·0
5 6 – 5 8 } 5 7	222·0	228·0	222·0
5 8 – 5 10 } 5 9	237·5	241·0	238·0
5 10 – 6 0 } 5 11	254·5	258·0	254·0
Mean of all heights -	214·0	217·0	214·0

The first column contains the heights between five and six feet, increasing arithmetically two inches at a time, as 1. 3. 5., &c.; the next two columns are the result of experiment; the first upon 1012 cases at an earlier period of the investigation; the next at a later period, when the whole cases conjoined amounted to 1923 cases. We found that the men from 5 feet to 5 feet 2 in. gave a mean vital capacity of 176 cub. in.; the men two inches taller a mean of 191 cub. inches; the next, 207 cub. in., and so on; thus the volume increases as we descend the column. Finding the progression so regular, we arranged a fourth column, containing a series of numbers in perfect arithmetical progression, commencing with 174, and increasing sixteen at every subsequent step, corresponding to the two inches of height successively added. We found, upon comparing the two columns of *observations* with the column of calculation, that there was a close resemblance. The increase of sixteen for every two inches is of course the same as eight for every single inch; hence the rule deduced upon nearly 2000 cases (and subsequently confirmed by double that number) viz. *That for every inch of stature, from* 5 *feet to* 6 *feet, eight additional cubic inches of air, at* 60°, *are given out by a forced expiration.* This brings the detailed matter of a series of tables and calculations into a point, and easy of remembrance, the more so as extended observations upon nearly 5000 men have brought the column of observation so close to the column of regular progression, that it is only necessary now to take the column of regular progression as a standard for examining the condition of the lungs as to their permeability for air, and the mobility of the thoracic boundaries.

If we recollect that at the height of 5 feet,

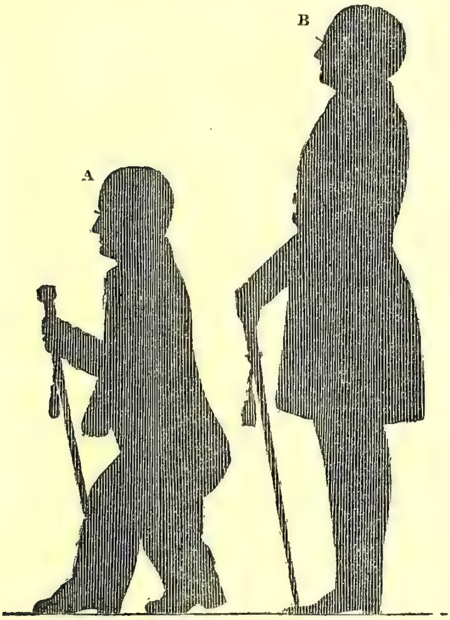
Table V. —Vital Capacity Volume (temp. 60° F.) necessary to Health at the Middle Period of Life.

Height. ft. in.		ft. in.	Vital capacity.
5 0	to	5 1	174
5 1	„	5 2	182
5 2	„	5 3	190
5 3	„	5 4	198
5 4	„	5 5	206
5 5	„	5 6	214
5 6	„	5 7	222
5 7	„	5 8	230
5 8	„	5 9	238
5 9	„	5 10	246
5 10	„	5 11	254
5 11	„	6 0	262

8 in. the vital capacity is 230, we can recollect the rest by adding or subtracting eight to or from this number, for every inch of stature above or below 5 feet 8 in., between 5 and 6 feet. These numbers may be taken as expressions of certain conditions of the thorax, an expression of mobility relative to breathing, and consequently an expression of the permeability of the lung. It therefore follows that whatever affects the mobility of the thoracic boundaries, or the permeability of the lungs, the *amount of that cause is expressed by the volume of the vital capacity.* Incipient disease is quick in affecting the vital capacity; the amount of the injury therefore is readily measured. We are at a loss to assign any just reason why the vital capacity is relative to the height, which is regulated by the length of the limbs, and not by the length of the trunk of the body. We have found by experiment, that whatever be the standing height, the sitting height is nearly the same in all persons of between 5ft. and 6ft., and if not actually the same, yet it is not a rule that the tallest men sit the highest; for instance, one man standing 6ft. 0¼in. measured from his seat 2ft. 11⅝in., whlie another who stood 5ft. 6in., sat 3ft. high; therefore the length of the trunk bears no constant proportion to the length of the legs. And we found that men who stood low, breathed less than men who stood higher, but who sat the same height. Thus *fig.* 706. represents two men; A. stood 4ft. 4½in., B. 5ft. 9½in.; they were of the same age and circumference of the chest. The weight of the short man was 7st. 2½lb., that of the taller man 10st. 3lb. Yet their sitting height was precisely the same, as is shown in *fig.* 707. Nevertheless, the vital capacity volume of the shorter man was 152, and that of the taller man 236 cubic inches; so that the man who stood the shorter, but who sat as tall, if not taller, breathed eighty-four cubic inches less than the man who stood seventeen inches higher. The mobility of the chest of the taller man was nearly four inches, that of the shorter man three inches. We examined several such cases with similar results. The average vital capacity volume at all heights is about 230 cubic inches. The greatest

we have examined was Randall's; height 7 ft. weight 22 st.; vital capacity 464 cubic inches. The smallest was Don Francisco; height 29 in., weight about 40 lbs.; vital capacity 46 cubic inches. The highest vital capacity at the height of 5 ft. 8 in. was 330 cubic inches.

Fig. 706.

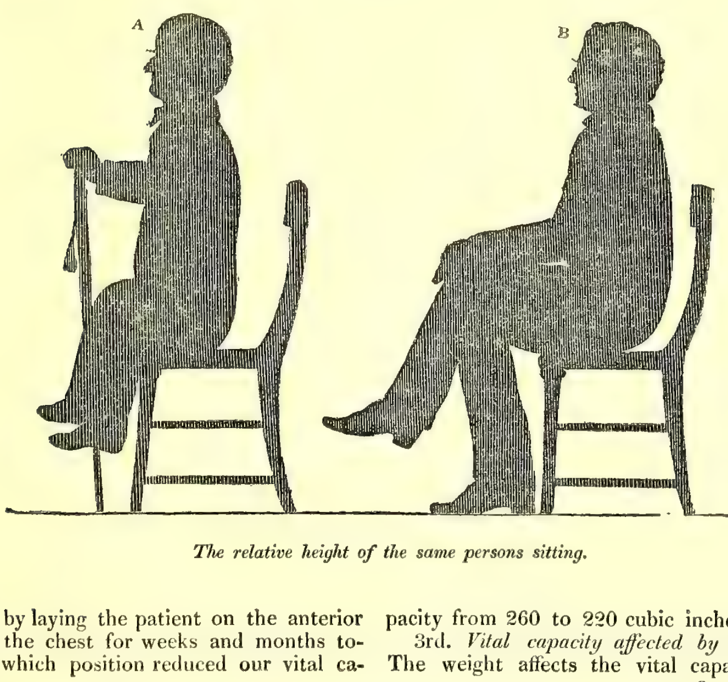


Relative height of two persons standing.

A question arises, are the lungs and thoracic parietes at their maximum stretch when they contain the appropriate vital capacity volume? We believe not. The vital capacity of the person from whom the preparations figured above (*figs.* 680. *et seq.*) were taken, whose height was 5 ft. 4 in., weight 107 lb., was 198 cubic inches; yet, after death, we forced 300 cubic inches of air into his lungs without rupturing them, being 102 cubic inches more than he could expire during life. Therefore there is still a spare mobility of parts, probably in reserve, to be exercised when disease attacks the lungs.

2nd. *Vital capacity affected by the position of the body.* — We have said a man must hold himself erect to breathe out a good volume of air; because the mobility of the ribs is affected by the uprightness of the spine; and, more than this, whatever touches the ribs affects their mobility, and consequently the vital capacity. Thus, standing, we have produced a vital capacity of 260 cubic inches; sitting erect 255 cubic inches; recumbent — supine 230, prone 220 cubic inches; position making a difference of 40 cubic inches. This may explain why patients with emphysematous lungs sit up in bed, and why for them to lie recumbent, is "suffocating;" because they thereby diminish the thoracic mobility. It may be well to recollect this effect upon respiration, in treatment of diseases of the spine, particularly at the present time, when they are treated by laying the patient on the anterior part of the chest for weeks and months together, which position reduced our vital capacity from 260 to 220 cubic inches.

Fig. 707.



The relative height of the same persons sitting.

3rd. *Vital capacity affected by weight.* — The weight affects the vital capacity; but as yet the relation does not appear so regular as that of the height. We are scarcely in a position, at present, safely to say much upon this point. As a general rule we find the weight increases with the height; so that it is not easy to separate the effect of one from that of the other. Suppose we take two men of the same stature, say 5 feet 8 inches, the one 10 stone, the other 14 stone in weight; one of them above par, the other may be either at, or below par. If 10 stone be considered par, the 14 stone man is 4 stone in excess, or corpulent to 40 per cent. This excess weight blocks up the range of mobility, and thus, mechanically, diminishes the vital capacity volume. But let us suppose men of dissimilar heigths, one 5 feet 8 inches and the other 6 feet; the 6 foot man should be heavier than the shorter man; — say 3 stone heavier. This is not excess weight with him, and does not interfere with his thoracic mobility; therefore there is an inseparable relation between the height and weight. If, in a series of experiments, we sink the height entirely, and keep the mere weight in view, we shall find that the result as to the vital capacity volume is without order.

Table W. — Vital Capacity Volume in Relation to *Weight*.

Weight.	Vital capacity.	Difference.	
st. st.		cub. in.	
7 to 8	166		
8 to 9	187	21	+
9 to 10	199	12	+
10 to 11	222	23	+
11 to 12	233	11	+
12 to 13	238	5	+
13 to 14	237	1	—
14 to 15	278	41	+

From this there is seen to be a rude increase of the vital capacity with the increase of the weight, but it is quite irregular, as 21., 12., 23., &c. We have also found the mean vital capacity of 147 men of 11 stone as 225 cubic inches, and that of 32 men of 14 stone, only 233 cubic inches, an increase of 8 cubic inches for an increase of 42 lbs., or 3 stone. The overwhelming effect of height disturbs the above observation; therefore the height must be kept in view. We have calculated the weights in *relation to height*, with reference to the respiratory function, upon a number of men at the middle period of life. Besides the three classes mentioned above, we have included 1554 cases of healthy men in the prime of life, obligingly furnished by Mr. Brent, viz. the Oxford and Cambridge rowers, London watermen, cricketers, pedestrians, and gentlemen (Table X). The weight now appears more regular, increasing with the height, as from 92 lbs. to 218 lbs. We may make this progression appear more regular, as in Table Y, which is calculated by adding the mean weight, from the last table, of the men from 5 feet to 5 feet 2 inches (the mean of which is of course 5 ft. 1 in.), together, and taking the mean of that, which will be found 119·9 lbs.; and the next from 5 feet 1 inch to 5 feet 3 inches, taking their mean as 126·1 lbs., and so on.

Table X. — Weight to Height, upon 3000 cases.

Height.	No. of Cases.	Gross Weight in lbs.	Mean Wt. in lbs.
Ft. In. Ft. In.			
4 6 to 5 0	26	2,399	92·26
5 0 „ 5 1	17	1,964	115·52
5 1 „ 5 2	36	4,476	124·33
5 2 „ 5 3	43	5,497	127·86
5 3 „ 5 4	88	12,145	138·01
5 4 „ 5 5	126	17,537	139·17
5 5 „ 5 6	214	31,016	144·93
5 6 „ 5 7	316	45,598	144·29
5 7 „ 5 8	379	57,822	152·59
5 8 „ 5 9	468	73,835	157·76
5 9 „ 5 10	368	61,238	166·40
5 10 „ 5 11	348	59,460	170·86
5 11 „ 6 0	245	43,475	177·45
6 0 „ 6 +	326	71,283	218·66
Total - -	3000	487,745	147·86

It thence follows, the range of stature from 5 feet 1 inch to 5 feet 11 inches is 10 inches; and the weight *rises* from 119·9 lbs. to 174·2 lbs., or 54·3 lbs.; or 5·43 lbs. with every inch of stature. To subdivide the range of height it may be said: —

Table Y. — *Difference* of Weight to Stature on 2648 males, from the last table.

Exact Stature.	Weight lbs.	Weight more exactly, lbs.	Difference of Weight in lbs.
Ft. In. In.			
5 1 or 61	120	119·9	+ 6·2
5 2 „ 62	126	126·1	+ 6·8
5 3 „ 63	133	132·9	+ 5·7
5 4 „ 64	139	138·6	+ 3·5
5 5 „ 65	142	142·1	+ 2·5
5 6 „ 66	145	144·6	+ 3·8
5 7 „ 67	148	148·4	+ 6·8
5 8 „ 68	155	155·2	+ 6·9
5 9 „ 69	162	162·1	+ 6·5
5 10 „ 70	169	168·6	+ 5·6
5 11 „ 71	174	174·2	

	lbs.		ft. in.		ft. in.
Their rise is	6·2	from	5 1	to	5 4
————————	3·3	—	5 4	„	5 7
————————	6·5	—	5 7	„	5 11

There is an inequality from 5 feet 4 inches to 5 feet 7 inches in the weight; but this would in all probability disappear if the observations were more extended; at present it may be stated generally that the weight increases 6·5 lbs. (or 6½ lbs.) for every inch of stature from 5 feet 7 inches to 6 feet, and 6·2 lbs. for every inch of stature from 5 feet 1 inch to 5 feet 4 inches, and 3·3 lbs. for every inch from 5 feet 4 inches to 5 feet 7 inches.

At 5 feet 8 inches, or 68 inches of stature, the weight is 155·2 lbs., or nearly 11 stone;

from this as a starting point the weight at any height may (so far as our limited observations warrant) be readily calculated. For instance, the weight is, at the height of 5 feet 8 inches, $\frac{155 \cdot 2}{68} = 2 \cdot 282$ lbs. for every inch of stature, or 27·38 lbs. for every foot of stature. The bulk or weight of bodies having the same relative proportions, is as the third power (cubes) of either of their diameters: thus, if a person 67 inches high weighs 148·44 lbs., a person 69 inches high should weigh $\left(\frac{69}{67}\right)^3 \times 148 \cdot 44 = \frac{69 \times 69 \times 69}{67 \times 67 \times 67}$ $\times 148 \cdot 44 = \frac{328509}{300763} \times 148 \cdot 44 = 162 \cdot 14$ lbs. The weight at that height, from *observation*, was 162·08 lbs., a similarity too close to be accidental.

The weights vary as the 2·75th power of the height, and not as the 3rd power. The relation between the two is quite close enough to show, that there is a very intimate connection between the height and the weight. The observation is made upon 1276 men at the middle period of life.

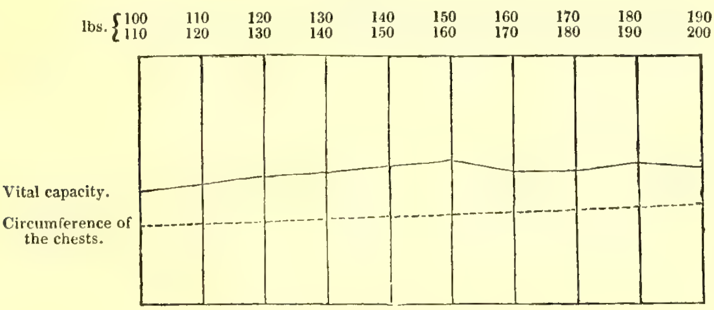
Taking the height from 67 to 71 inches, we have as follows: —

Table Z.—The *calculated* Weight compared with the *observed* Weight, according to the above Form.

Height in Inches.	Weight determined by Calculation.	Weight determined by Observation.
in.	lbs.	lbs.
67	148·8	148·4
68	155·5	155·2
69	162·1	162·1
70	169·3	168·6
71	176·6	174·2

We have found that the vital capacity increases 42 cubic inches with the weight from 100 lbs. to 155 lbs., and from 155 lbs. to 200 lbs. the effect is balanced by minus 5 and plus 5 cubic inches. In the first division there is an increase of 42 cubic inches; the weight then comes into power, and disturbs the regular progression for the next division; therefore we may say there is in the second division a *decrease* of 42 cubic inches in the vital capacity volume from the effect of weight. We represent this by a curve, *fig*. 708. The continuous curve is the line of vital capacity crossing the perpendicular lines of progressive weights.

Fig. 708.



The Effect of Weight on the Vital Capacity.

The curve of volume ascends, and attains its highest at 160 lbs., and from thence it is nearly horizontal to 200 lbs. According to this, the vital capacity increases nearly in the ratio of 1 cubic inch per lb. from 105 to 155 lbs., and from 155 to 200 lbs. there is no increase. This illustration of the effect of weight is calculated at one height, viz. 5 feet 6 inches; therefore to this height *only* these points of weight (from 11½ to 14 stone) refer. We have noticed that the weight increases in a certain ratio with the height, and that the weight at 5 feet 6 inches affects the vital capacity in the relation just mentioned, commencing when the weight exceeds 7 per cent upon the average weight. We may, perhaps, connect this same relation with the other heights through the arithmetical progression of inch by inch. For example: — the weight of men of 5 feet 1 inch is 199·9 lbs.; to this add 7 per cent (8·395 lbs.), making 128·2 lbs.; again, the tallest men, 5 feet 11 inches, weigh 174·2 lbs.; to this add 7 per cent (12·2 lbs.), making 186·4 lbs.: therefore, at the height of 5 feet 1 inch a man must exceed 128 lbs., or 9 stone 2 lbs., and the 5 feet 11 inches' man 186 lbs., or 13 stone 4 lbs., before weight may be expected to diminish the vital capacity volume in the relation of 1 cubic inch per lb. for the next 25 lbs., 2½ stone being the limit of our calculation. When the man exceeds the mean weight (at each height) by 7 per cent, the *vital capacity decreases* 1 *cubic inch per lb. for the next 35 lbs. above this weight.* Beyond this it is not improbable but that the decrease of the vital capacity is in some geometrical progression. Below the mean weight we have never found by experiment, that the vital capacity is affected by weight.

The cause of the difference of weight between men is involved in much obscurity.* We may in fact consider the usual weight of a man as his mean weight and

* See Chambers, Gulstonian Lect. 1850.

TABLE A A. — Effect of *Weight* on the Vital Capacity (Age sunk).

Heights.	lbs. 100 110	Chests.	Cases.	lbs. 110 120	Chests.	Cases.	lbs. 120 130	Chests.	Cases.	lbs. 130 140	Chests.	Cases.	lbs. 140 150	Chests.	Cases.	lbs. 150 160	Chests.	Cases.	lbs. 160 170	Chests.	Cases.	lbs. 170 180	Chests.	Cases.	lbs. 180 190	Chests.	Cases.	lbs. 190 200	Chests.	Cases.
ft. in. ft. in.	c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.		
5 0 to 5 1	177	30	3	187	31	3	141	34	2	140	33	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5 1 to 5 2	178	31	8	156	32	6	180	32	2	174	33	4	196	34	1	...	...	...	...	...	...	150	37	1	...	...	...	...	...	...
5 2 to 5 3	173	30	1	169	31	4	190	32	6	192	34	6	172	33	2	234	37	2	174	37	1	...	...	...	186	40	1	...	...	...
5 3 to 5 4	188	30	3	181	32	6	175	32	17	184	34	20	201	34	13	227	37	2	145	37	1	182	38	7	119	38	2	...	...	...
5 4 to 5 5	168	29	2	168	31	12	182	32	17	190	33	19	206	34	20	207	34	10	181	38	6	...	...	...	...	...	...	...	...	...
5 5 to 5 6	...	...	...	170	33	4	196	33	16	188	33	39	208	34	37	208	35	20	202	36	10	176	38	3	218	38	2	...	...	...
5 6 to 5 7	...	...	...	198	33	3	219	32	31	216	33	40	223	34	60	224	34	25	223	36	13	191	38	5	229	41	2	184	39	3
5 7 to 5 8	...	...	...	228	31	5	215	32	12	197	34	32	221	34	74	209	35	41	227	36	32	214	38	9	224	31	5	182	39	2
5 8 to 5 9	...	...	...	196	33	1	200	31	9	213	33	23	220	35	50	211	35	40	242	36	45	228	37	18	231	38	9	220	39	4
5 9 to 5 10	...	...	...	200	31	1	241	32	3	235	33	10	241	34	22	239	36	30	244	36	32	274	38	15	246	38	7	214	39	5
5 10 to 5 11	...	...	...	195	30	1	185	31	2	208	33	2	254	34	8	238	36	20	217	35	18	248	38	13	278	38	8	237	38	5
5 11 to 6 0	...	...	...	...	...	...	...	...	...	243	33	2	244	35	5	264	36	16	259	36	13	251	37	34	261	38	10	263	41	5
6 0 to 6 +	...	...	...	...	...	...	...	...	...	260	33	2	243	36	2	253	35	4	279	39	11	281	37	17	274	38	16	275	39	10
Total mean...	176	30	17	186	31	46	196	32	117	203	33	201	219	34	294	228	35	210	217	36	182	219	37	112	226	38	62	221	39	35

the term "gained weight" should be understood as weight *superadded* to his *usual* weight, or mean weight in the above Table. Thus, if a man may lose weight below his usual weight, he should gain above his usual weight before he can be said to have *gained weight*.

The effect of weight in diminishing the respiratory volume, need not in the least disturb the observer, when testing the lungs through the measurement of the vital capacity, with reference to phthisis or any other chest disease. For collateral observations and the history of the case, will sufficiently protect him from such difficulty. We see that the weight increases at so much per inch; we have no doubt that by extended observations it will be found to be regular through the whole series of heights, and that it will be found to increase 7 lbs. for every inch of stature. We know that the respiratory power increases in a similar arithmetical relation. We do not mean that the lb. will correspond to the inch, for that is accidental, merely depending upon the units employed, but that the increase of each will be found in an arithmetical progression, and hence, probably, the reason why tall men breathe more than short men.

But the weight can never be the sure guide that the height is, because the former varies at any time in life, even in a few days; whereas the latter varies only at the extremes of life.

4th. *Relation of vital capacity to the circumference of the thorax.* — We notice this here, because the question is so natural, "Has the size of the chest no relation to the vital capacity?" We do not find that there exists any direct relation between the circumference of the chest and the vital capacity. We have found —

Men.	Height. ft. in.	Circum. in.	Vital capacity.
11	5 8	35	235
10	5 8	38	226

Therefore, the men with chests 3 inches larger, breathed 9 cubic inches less, or 21 men of the same height, but of different-sized chests, breathed a mean vital capacity of 230 (the due quantity according to TABLE T). We have consolidated the following result upon 994 cases, the height is kept in view, calculated at 5 feet $6\frac{1}{2}$ inches.

TABLE B B. — Circumference of the Chest, in Relation to the Vital Capacity Volume, in 994 cases (Males).

Circumference of Chest.	Vital Capacity.	Number of Cases.	Cubic In. Difference.
30 to $30\frac{1}{2}$	200	14	−13
$30\frac{1}{2}$ „ 31	187	20	+18
31 „ $31\frac{1}{2}$	206	21	−10
$31\frac{1}{2}$ „ 32	196	35	+ 1
32 „ $32\frac{1}{2}$	197	32	− 7
$32\frac{1}{2}$ „ 33	204	50	− 2
33 „ $33\frac{1}{2}$	202	44	0
$33\frac{1}{2}$ „ 34	202	63	+63
34 „ $34\frac{1}{2}$	213	70	+ 4
$34\frac{1}{2}$ „ 35	217	78	− 2
35 „ $35\frac{1}{2}$	215	71	+14
$35\frac{1}{2}$ „ 36	229	74	−10
36 „ $36\frac{1}{2}$	219	59	+ 2
$36\frac{1}{2}$ „ 37	221	97	+18
37 „ $37\frac{1}{2}$	239	59	− 4
$37\frac{1}{2}$ „ 38	235	57	−13
38 „ $38\frac{1}{2}$	222	41	+ 8
$38\frac{1}{2}$ „ 39	230	40	− 6
39 „ $39\frac{1}{2}$	224	18	+ 2
$39\frac{1}{2}$ „ 40	228	37	−11
40 „ $40\frac{1}{2}$	217	14	0

There is nothing in this table to confirm that which we had thought would be the main guide to the vital capacity volume; thus, compare together the first and last 14 men whose chests differ 10 inches, and their vital capacity only 17 inches; or compare together the first and last columns, the one is perfectly regular and the other most irregular. There is a certain rude relation between the thoracic dimensions and the vital capacity; if, for instance, one man has a chest 35 inches in circumference, and 3 inches mobility, and another man has a chest 40 inches in circumference, and 4 inches mobility, then the latter will surely displace a larger volume of air than the former, but omitting this, we expect as large a vital capacity from a man with a thin and narrow thorax, as from a man with a broad and deep thorax. In fact, aëration need have no relation to the thoracic dimension; and, for the same reason, the size of the chest no relation to the vigour of the whole man. Indeed we incline to the contrary, viz. that it is most likely the respiration is most vigorous in the narrow-chested man, when the mobility is greatest. The vigour of the lungs, like every other organ in the body, we believe, has no relation to the dimensions. One person may have a brain 1 lb. lighter, or $\frac{1}{3}$ less than another person, and yet their capacity and mental qualities shall not appear different.

5th. *Vital capacity affected by age.* — Age affects the breathing movements, but less remarkably than the height and weight. Indeed the influence of age was not apparent in the first calculation upon 1012 cases, nor until we took a basis of 1923 cases. Time affects life in two ways, first bringing it to perfection, and then determining that perfection.

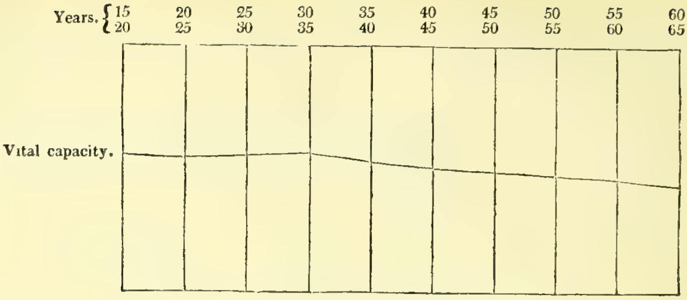
TABLE C C. — Effect of Age, from Observations on 1775 healthy Men, the Height being kept in View.

Age.	Cubic Inches.	Cases.	Circumference of Chest.	Vital capacity for every 10 Years.	Difference.
15 to 20	220	283	34	220	+ 5
20 „ 25	220	491	34		
25 „ 30	222	347	34	225	−19
30 „ 35	228	242	35		
35 „ 40	212	171	34	206	−11
40 „ 45	201	93	35		
45 „ 50	197	55	35	195	−13
50 „ 55	193	37	36		
55 „ 60	182	30	36	182	
60 „ 66	183	26	35		
Mean of all ages	205·8	1775	35		

The column of "*difference*" exhibits the effect of time upon the breathing volumes.

From 15 to 35 years of age the vital capacity is increased, and from 35 to 65 years of age it is decreased in the progression of 19, 11, and 13 cubic inches. We illustrate this by a curve in *fig.* 709. The curve of the vital capacity will be seen to rise slightly as it passes the perpendicular lines of years until it comes to 35 years of age, after which it keeps declining as it cuts all the succeeding lines of quinquennial periods down to 65 years. We may say, therefore, that the vital capacity increases with the age up to

Fig. 709.



The Effect of Age on the Vital Capacity.

30 years, and from 30 to 60 it decreases 43 cubic inches, or 1·43 (nearly 1½ cubic inches) per year, or 7 cubic inches in 5 years, or 14⅓ cubic inches in 10 years. Although this appears by calculation, yet we do not strictly follow this ratio, as we find by experience that the effect of age may be more diminished, as follows: —

TABLE D D. — Vital Capacity at three Periods of Life, from 4800 cases (males).

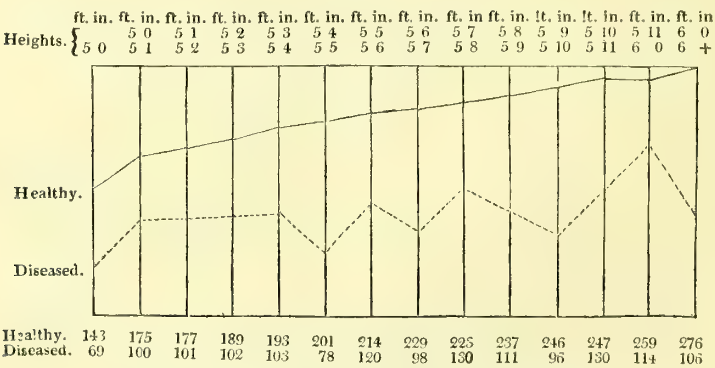
Height. ft. in. ft. in.	Vital Capacity. Age from 15 to 55.	Vital Capacity. Age from 55 to 65.	Vital Capacity. Age from 65 to 75.
5 0 to 5 1	174	163	161
5 1 „ 5 2	182	173	168
5 2 „ 5 3	190	181	175
5 3 „ 5 4	198	188	182
5 4 „ 5 5	206	196	190
5 5 „ 5 6	214	203	197
5 6 „ 5 7	222	211	204
5 7 „ 5 8	230	219	212
5 8 „ 5 9	238	226	219
5 9 „ 5 10	246	234	226
5 10 „ 5 11	254	242	234
5 11 „ 6 0	262	249	241

From 55 to 65 we have deducted 5 cubic inches per cent, and from 65 to 75 years of age 8 cubic inches per cent. We have not brought in the effect of time before the age of 55 years. This is supposed to be at the mean weight. The first column is derived from observation, the two second are derived from calculation.

6th. *Of the effect of disease upon the vital capacity.* — The effect of disease upon respiration was well known to Boerhaave and Morgagni, they considered that the disturbance of any organ in the body would disorder the whole function of respiration. Morgagni devotes more than one-sixth of his celebrated work, the "*Seats and Causes of Disease*," "to *diseases which affect respiration.*" We may safely say all thoracic and abdominal diseases, as tumours, abscesses, and acute inflammations, will affect the respiration. Of the different respiratory volumes, we select that one which requires the most extended mobility, viz. the vital capacity, which becomes altered to an extent commensurate with that of any disease physically affecting our respiration, it is therefore a test of the presence and extent of such diseases. Such movements as command this volume, extend from the neck to the plantar muscles of the feet.

One condition which we have been accustomed to look upon as affecting our breathing, does not affect it, viz. old pleuritic adhesions.

Fig. 710.



Vital Capacity of the healthy and diseased Cases compared.

We met with a case in which the lungs could not, in consequence of pleuritic adhesions, be removed from out of the thorax; indeed there was not one square inch of pleura which was not firmly adherent. The lungs had to be torn out by little pieces, and so strong was the adhesion to the diaphragm, that in removing them this muscle was ruptured, yet the living respiratory mobility of the thoracic walls exceeded by three inches the whole thoracic space allotted for the heart and lungs, as measured after death. This space to the mobility was as 248 to 251. In other respects the lungs were healthy.

Of all diseases, phthisis pulmonalis most readily affects the vital capacity, not only when the lungs are beginning to be infiltrated with tubercular matter, but probably before this.

This is shown in *fig.* 710. Taking all the cases together, the difference is about 50 per cent.

The effect of this disease upon the vital capacity in the case of Freeman was very remarkable. This man came from America in 1842 "trained for a *prize fight.*" He was examined when in his "*best condition*," and his vital capacity measured 434 cub. in. (temp. 60°); height, 6 ft. 11¾ in.; weight, 19 st. 5 lbs.; circumference of the chest, 47 in.; inspiratory power, 5·0 in.; expiratory power, 6·5 in. Freeman fought his battle, and for the subsequent two years lived a rambling and dissolute life. In November, 1844, exactly two years afterwards, he came to town in ill health. At this time there was no auscultatory evidence of phthisis pulmonalis; but the following difference appeared in his vital capacity-volume:

	Vital Capacity.	Weight.		Inspiratory Power.	Expiratory Power.
	cub. in.	st.	lbs.		
Nov. 1842 -	434	19	5	5·0	6·5
Nov. 1844 -	390	17	5	4·0	5·0
Dec. 1844 -	360	16	0	3·5	4·0
,, -	320	15	5	—	—

In October, 1845, he died at the Winchester hospital; and Mr. Paul, surgeon to that charity, stated that Freeman died of extreme exhaustion and debility, expectorating pus; and that his lung was throughout studded with tubercles; his weight at death was 10 st. 1 lb.; height, 6 ft. 7½ in. Another remarkable case was that of a man of perfectly healthy appearance, and in whom there was no auscultatory or general sign of organic disease, but whose vital capacity was deficient by 47 cub. in.; and it was found, within three days of the time when he was examined, that the left lung at the apex was studded with miliary tubercles, the whole not extending beyond a square inch.

In diseases of the spine, particularly in angular curvature, the mobility is changed sometimes to such a degree that the vital capacity is diminished to 20 cub. in. A full meal will even make a difference in the thoracic mobility, of from 12 to 20 cubic inches. If the vital capacity is deficient, there must be some *cause* producing the *effect.* It may or may not be in the thoracic cavity. Collateral observations must point more definitely to the diseased part. The spirometer is only a gauge to measure the mobility and permeability of the lung; other circumstances must point out the *cause* of the mobility and permeability being affected. Taking the observations upon the diseased cases by calculation, the vital capacity volume may be arranged for all heights as follows: *

Table E E.—Effect of Phthisis Pulmonalis upon the Vital Capacity.

Height.	Health.	Suspicious Cases, 16 per Cent.	1st Stage. 33 per Cent.	2d Stage.	Mixed. 43 per Cent.
ft. in. ft. in.					
5 0 to 5 1	174	146	117	82	99
5 1 ,, 5 2	183	153	122	86	102
5 2 ,, 5 3	190	160	127	89	108
5 3 ,, 5 4	198	166	133	93	113
5 4 ,, 5 5	206	173	138	97	117
5 5 ,, 5 6	214	180	143	100	122
5 6 ,, 5 7	222	187	149	104	127
5 7 ,, 5 8	230	193	154	108	131
5 8 ,, 5 9	238	200	159	112	136
5 9 ,, 5 10	246	207	165	116	140
5 10 ,, 5 11	254	213	170	119	145
5 11 ,, 6 0	262	220	176	123	149

The question naturally arises, How far deficient of the standard may be the vital capacity without indicating disease? It has been found that ten cubic inches below the due quantity, *i. e.* 220 instead of 230 inches, need not excite alarm; but there is a point of deficiency in the breathing volume at which it is difficult to say whether it is merely one of those physiological differences dependent on a certain irregularity in all such observations, or deficiency indicative of disease. A deficiency of 16 per cent. is suspicious. A man below 55 years of age breathing 193 cub. in. instead of 230 cub. in., unless he is excessively fat, is probably the subject of disease.

In phthisis pulmonalis the deficiency may amount to 90 per cent., and yet life be maintained. The vital capacity volume is likewise a measure of improvement. A phthisical patient may improve so as to gain 40 upon 220 cub. in.

Of the Respiratory Movements.—The breathing volumes have been divided into three kinds; so likewise the breathing movements admit of a similar division,—one ordinary and two extraordinary movements.

By the independent action of the intercostal muscles, *every* intercostal lamella can act separately, therefore we have the thorax furnished with 22 spaces by which it can enlarge; and

* See "Spirometer Observations," First Report of the Hospital for Consumption, p. 23. *et seq.* Lond. 1849.

the diaphragm acting as one muscle, makes 23 mobile regions for respiration.

The respiratory movements of health may be classed as *costal* and *abdominal.* The character should be established by the *order* in which they follow each other. In health the walls of the thorax and the floor do not dilate *simultaneously* but *consecutively.* The character of "*the breathing*" cannot always be told by the eye, but it can always be determined by the touch. If we stand behind a patient, when seated and leaning against the back of the chair or against our person, and pass the right arm over the shoulder, extending it over the anterior part of the chest, until the hand rests upon the abdomen over the umbilical region, we command a delicate index of the breathing movements. It will then be found, that in ordinary *male* breathing the abdomen first bulges outwards; the ribs and sternum nearest the abdomen gently follow this movement, until the motion, like a wave, is lost over the thoracic region. The undulation *commences* at the abdomen. This is *aoaomina, or diaphragmatic* respiration. We here have costal *motion,* but as the ribs moved second it is not called costal breathing.

In *costal* breathing the upper ribs move *first,* and the abdomen *second.* This is the ordinary breathing in women.

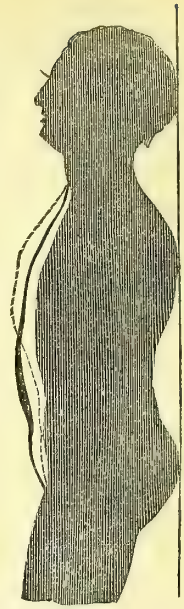
All difficult, sudden, and extraordinary breathing is costal; we at such times direct all our power towards the apex of the thorax, first expanding that region, and gradually those below it.

When we determine the order of breathing by the sight, we must be careful to take the position of the body into account. If the patient be recumbent (supine), we may notice extensive costal motion, and, indeed, it may be true costal breathing; but place the patient erect, and the breathing may be diaphragmatic. When recumbent, all the motion is thrown forwards, the natural backward and lateral motion of the ribs being prevented; and so sensitive are the breathing movements to impediments, that they may either take a reverse action, or all the motion being thrown forwards, will give a preternatural movement of the ribs, which may be mistaken for costal respiration.

Profile view of the breathing movements—(*a*) *Ordinary breathing* (Male).—*Fig.* 711 was obtained by tracing the shadow of a man on paper. The back was fixed, so as to throw all the movement forwards. The anterior black, continuous line represents the ordinary breathing. This line is thicker over the abdomen than elsewhere. The anterior margin of this line indicates the boundary of the ordinary *inspiration,* and the posterior margin the boundary of the ordinary *expiration.*

(Female).—This is represented by the anterior continuous line in *fig.* 712., in the same manner as shown in the male. This line in the female is broadest over the sternum, and narrow over the abdomen. The movement over the abdomen of the female is so small, that the number of the respirations cannot be counted by the hand resting on that region as it can be on the male. The question of why women breathe costal, and men abdominal, we cannot pretend to answer. We doubt its being caused by any tight costume, for we found the same to exist in twenty-four girls between the ages of eleven and fourteen, none of whom had ever worn any tight dress. This peculiarity may be a reservation

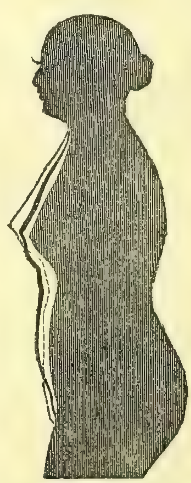
Fig. 711.



Respiratory Movements. Male.

Deep inspiration, dotted line; ordinary state, continuous line; deep expiration, anterior margin of the shade.

Fig. 712.

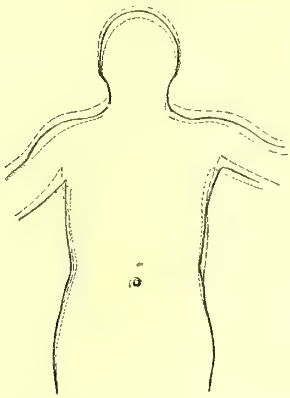


Respiratory Movements. Female.

Inspiration, dotted line. Ordinary, continuous line. Expiration, anterior margin.

against the period of gestation, when the abdomen cannot allow of so free a descent of the diaphragm.

Fig. 713.

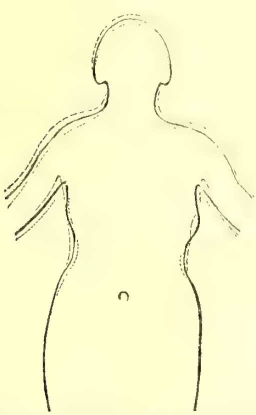


Respiratory Movements. Male. Front view.

Inspiration, broken line. Ordinary, continuous line. Expiration, dotted line.

The *lateral* movement of ordinary breathing is too limited to be represented by a line of varying thickness: the position is given by the continuous line, *figs*. 713. and 714.

Fig. 714.



Respiratory Movements. Female. Front view.

Inspiration, broken line. Ordinary, continuous line. Expiration, dotted line.

(*b*) *Deep inspiratory.* — In *fig*. 711. the dotted line shows this position, as when a man is just ready to displace his vital capacity-volume. The sternum is *protruded* and the abdomen is *drawn in*. This is the same in the female (*fig*. 712.), the dotted line is most advanced over the sternum, while over the abdomen it is drawn inwards.

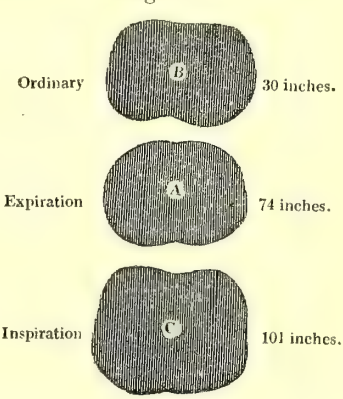
So much is the abdomen drawn inwards by deep inspiration, that the portion of the continuous line (*figs*. 711, and 712.), representing the ordinary breathing is (over the abdominal region) *external* to the dotted line of deep inspiration. Therefore the greatest enlargement of the thoracic cavity in both sexes is made by the ribs, and not by the diaphragm, as is generally believed. It appears very questionable whether the diaphragm is any thing more than flattened and that without descending.

Of the position of the diaphragm. — It is clear that all that space between the line of ordinary breathing and deep inspiration (*fig*. 711.), below the ensiform cartilage, where the two lines cut each other, may be considered as just so much space deducted from the abdominal cavity; and therefore the abdominal cavity, by deep breathing, is just so much *less* than it was in the position of ordinary breathing. Now, if the diaphragm descends at this moment, whilst the abdominal parietes are being constringed on all sides, what becomes of the abdominal viscera? We know that in ordinary breathing the abdomen advances because the diaphragm descends, and recedes because the diaphragm ascends. We may suppose the same accommodating movement between the diaphragm and abdominal parietes, to take place in deep breathing. There can be no doubt that the circumference of the thorax is increased, as shown in D. *fig*. 670., and that the diaphragm must extend its borders, and consequently the arch must be flattened; but this may be without descending. We see (*fig*. 670.) that the section of the thorax to the area of the diaphragm is as 40 to 133 — the concavity of the diaphragm is enough to admit of its circumference expanding without its descending.

Fig. 715. is a diagram of sections of the base of the living chest in three stages. B is the chest in ordinary: A, as in extreme expiration; C, as in extreme inspiration. In this case the vital capacity was 305 cubic inches, and the mobility of the chest was 5 inches, a range by no means common. The area of the chest varied 27 superficial inches between extreme inspiration and expiration.*

In the sitting posture the same relations

Fig. 715.



Sections of the base of thorax in the three stages of respiration, in the living subject.

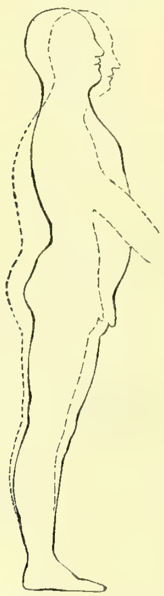
* This is the chest of *fig*. 711.

exist in the breathing movements; the only difference being that these movements are more limited.

(*c*) *Of the deep expiratory position.* — In *figs.* 711. and 712. the margin of the shade is the position of the thoracic boundaries in deep expiration.

We have supposed the figures above mentioned as standing with the back fixed, for the purpose of making clearly manifest the relative position of these several breathing movements. In *fig.* 716. the body is quite free, and wholly alters its position in performing expiration and inspiration. This should always be considered in noticing the breathing movements in diagnosis.

Fig. 716.



Respiratory Movements. Male, standing.

Expiration, dotted line. Inspiration, continuous line.

(*d*) *Of the change of position by extreme breathing.* — In expiration the head is *protruded* and *lowered* (see *figs.* 713. and 714.). Therefore, by inspiration the body is raised, and the more erect the more can be inspired; by expiration it is *lowered*, so much so that we have seen men when displacing their vital capacity volume stoop themselves to *one-half* their natural height, to one-sixth frequently: we speak from a large number of cases,— nearly 4000. Physiologists have reasoned that, as upon the principle of a bladder becoming longer when empty than when inflated, so the chest is shorter when inflated than when empty. But this example in no way corresponds. The bladder expands, because it is inflated; the chest is inflated because it expands.

We have given the *position* of the breathing parts (the body fixed): we shall describe the movement of these parts relatively in time and order to each other, and the peculiar character of these movements in health, and some of their modifications by disease.

Ordinary breathing.—*In men* this is symmetrical, and very limited, and commences with an advancing and receding of the *abdomen* at and above the umbilical region, accompanied with a slight lateral enlargement, and immediately followed by a bulging outwards at the cartilages of the 7th, 8th, 9th, and 10th ribs, and that part of the abdomen contiguous to them, with a slight advance of the lower third of the sternum. This is *abdominal* breathing, because the abdomen moves first; and is confined to motion of the base of the thorax. *In women* it is likewise symmetrical, commencing with a gentle heaving of the upper part of the *thorax*, more or less apparent according to the fulness of the mammæ. This expansion commences with the 1st and next three ribs following each other in succession, accompanied with a slight elevation of the shoulders and a slight lateral enlargement of the chest, which is *immediately* followed by a bulging outwards of the abdomen. So quick is this motion of the diaphragm after the motion of the ribs, that at times they appear to be synchronous, especially when the individual examined is conscious of the observation, though it is only an accommodating movement of the diaphragm. This is *costal* breathing, because the ribs move first, and the motion is chiefly confined to the apex of the thorax. Therefore that which is a healthy respiratory movement in women is pathological in men.

Of the extraordinary breathing in both sexes (*Inspiration*). — This, like ordinary breathing, is symmetrical: the clavicles, shoulders, scapula, and superior ribs are raised, the sternum advances, the infra-clavicular region swells remarkably upwards and outwards (particularly in females) like a rolling wave, the supra-clavicular region is raised but this sometimes appears comparatively deepened (merely by the action of the sterno-cleido-mastoideus), the whole apex of the thorax is rendered more obtuse, particularly in the antero-posterior diameter. The lower ribs, at their cartilaginous extremities, spread outwards, increasing both the lateral and the antero-posterior diameter of the base of the thorax, the cartilaginous (gothic) arch formed by the junction of the 6th, 7th, 8th, 9th, and 10th ribs below the sternum, becomes more obtuse by their lateral motion, the abdominal space within this arch, down to the umbilicus, *sinks inwards.* Therefore this breathing is costal, commencing with the superior ribs, and terminating over the abdomen. The peculiar character of healthy breathing (and it is impossible to lay too much stress upon the movements of deep inspiration, because they are so indicative of thoracic disease) is that the ribs expand in succession. There is an indescribable undulating roll, produced by the consecutive action of the respective ribs, which *always* commences with a superior rib; — in costal breathing, a lower rib *never* moves first. In fact when we inspire deeply we feel as if we directed all our power to the four or five superior ribs, giving the greatest expansion to the very apex of the lungs, — that most vulnerable part in phthisis pulmonalis. When we look at the thoracic cavity we see why this great power and mobility is given to the upper part of the chest. We see that the six superior ribs encompass more space than the six inferior ribs. (See *fig*. 668.) So that where we command most movement, there is the greatest portion of lung to be expanded. The hand can measure most delicately this healthy characteristic swelling or filling up of the apex better than any instrument, because the hand covers a large field of the chest, and can distinguish the *undulating* movement. Standing behind the person to be examined, the fingers of both hands should be placed over the clavicles, so that the tips rest on the infra-clavicular regions, and the thumbs over the inner borders of the scapulæ. When a deep inspiration is taken the fingers and thumb of each hand diverge from each other, and we thus gain a perfect knowledge of the healthy "swelling expansion." If the deep respiratory movement is good, the ordinary movement is sure to be good likewise. The mere flat hand on the anterior and upper part of the chest (facing the patient) will likewise give the character, though less delicately. This movement or swelling of the apex by deep inspiration, is more distinctly marked on the female than on the male subject. If this fine swelling motion in deep breathing is absent disease is present.

Pathological respiratory movements. — We now speak of another class of breathing movements, which are peculiar in this respect, that the "undulating swell" of the chest is wanting. The twelve intercostal muscles move in every combination, as if to meet impending difficulties, — tenacious of life, and yielding only by compulsion to the advance of disease. Throughout the long list of diseases which attack man these instinctive movements have to contend, — shifting about, or growing less and less. We have noticed a man with lung disease, commence with costal respiration of the lower ribs, and, as disease advanced, he breathed with ribs higher and higher up, so that at last he said, "I breathe with my neck;" and in truth it appeared so. His 1st, 2nd, and 3rd ribs only appeared to move. He passed through almost every variety of respiration before he died.

The breathing movements are quick to change, and the inquiry is interesting, what causes the change? One great cause is the existence of dyspnœa, a disproportion between the air passages and the volume of air to be displaced, which may be caused by an obliterated state of lung, by tubercles, fluid in the pleuræ, hypertrophy of the heart, aneurism of the great blood vessels, tumours of various kinds, the pain of local inflammation, pressure from the abdomen, whether ascites, obesity, distended stomach, gravid uterus, or any morbid growth bordering on the thoracic cavity, or lesion of nervous integrity requisite for maintaining the respiratory movements.

Such conditions of themselves would occasion deranged breathing movements. But again there are reasons for thinking that these movements may be changed from other causes not so purely physical; because sometimes no dyspnœa is to be perceived, and yet the movements are deranged, or they may change backwards and forwards as if aërating specific portions of the lungs, acting as a curative remedy to some incipient form of lung disease. In complicated diseases of the chest a knowledge of the breathing movements is highly useful. There is one condition in the respiratory act, which is indicative of a certain state of chest, which, if not useful as a positive, is at least so as a negative evidence of some existing state of things in the lungs.

The condition we allude to is a sinking in and bulging out of portions of integuments which cover the thoracic cavity. If we close both nostrils and make a violent *inspiratory* effort, the integuments between the sterno-cleido-mastoidei immediately above the sternum, will be seen to sink inward from atmospheric pressure. If we open one nostril, the same is less apparent. If both are open and the passages are free, it is not perceptible. In *expiration* (with the same obstruction) there is a bulging outwards of these integuments. Sometimes, particularly in thin persons, this may be seen on the integuments covering the intercostal spaces. This sinking inwards is an evidence of attenuated air, and the bulging outwards of condensed air in the lungs, near to the part. It is therefore an evidence of some *obstruction* in the air passage.

Difficult breathing may be attended with this feature, or not; therefore it is an evidence of something existing in one state of dyspnœa which does not exist in another.

Dyspnœa without this "sinking or bulging" is a proof that there is no obstruction between the air cells and the external air. But, on the contrary, dyspnœa with this "sinking and bulging," is a proof that there exists some obstruction either as a direct diminution in caliber of the air tube, or that more air is drawn through certain tubes than is natural; that this obstruction must have air on both sides of it, and that the air on one side is more attenuated than on the other. For instance, when an aneurism on one of the large vessels of a well-developed chest is pressing upon one of the large bronchi, the respiratory sounds, and those elicited by percussion, may be good, but respiration becomes laboured, — the case is obscure, but if there is alternate sinking and fulness of the lower part of the throat, we may be sure that there is some definite obstruction in the air passages. This, in connection with the history of the case, may lead to the detection of the cause and seat of the disease; but dyspnœa without this feature could not be caused by an aneurism or tumour.

In emphysema of the lung this sinking and bulging is very manifest. This circumstance proves simply that there is air in the chest of different density to the external air; and if so, there must be some impediment in the air tubes, preventing the restoration of atmospheric equilibrium.

Disease of the thoracic viscera affects the breathing movements, causing them to be more limited, or non-symmetrical, reversed, massive, interrupted, partial, quick, slow, irregular, or double.

(a) *Of limited breathing movement.* — The mobility of parts when disease attacks the chest may be surprisingly drawn forth. Haller allows scarcely any mobility to the first rib; Magendie asserts that the lower ribs are immovable, because they either reasoned from the healthy body, or anatomically: but it is not uncommon in phthisical patients to see strong and well-marked respiration kept up by the 1st, 2nd, and 3rd ribs, or by the 10th, 11th and 12th; — these ribs are movable, but it requires disease to bring their mobility forth. We are satisfied that there is a latent respiratory mobility during health, which is manifested only by disease.

In disease particular parts take up exaggerated movements, but the sum of these movements is more limited than in health. In the earliest cognisable stage of phthisis pulmonalis the expansion of the thoracic apex is diminished; the shoulders incline forwards and inwards, and become rounded; the spine is less erect; the apex cannot expand. The mobility of the inferior ribs does not so diminish, but sometimes maintains life to the last. With an exaggerated movement, the respiration is frequently costal and abdominal at the same time, as if no part could afford to be unemployed.

In 233 cases of phthisis pulmonalis (males) in the first stage we noticed that the breathing of 46 was costal, of 96 abdominal, and of 91 costal and abdominal. The mobility by tape measure was, instead of 3 inches and upwards, as follows: —

Table F F. — Diminished Mobility over the Nipples on 233 Phthisical Males.

Difference between Inspiration and Expiration.	Number of cases.
$\frac{1}{2}$ in.	3
$\frac{3}{4}$	5
1	54
$1\frac{1}{4}$	13
$1\frac{1}{2}$	44
$1\frac{3}{4}$	23
2	53
$2\frac{1}{4}$	12
$2\frac{1}{2}$	25
$2\frac{3}{4}$	1

(b) *Of non-symmetrical breathing movements.* — In advanced stages of phthisis pulmonalis non-symmetrical movements are noticed; but this may exist without a cavity or effusion of fluid in the lung; or a cavity may exist with symmetrical movements (but a cavity never exists without extensive diminution of mobility). *Generally* a cavity is attended with non-symmetrical movements, or a dragging up of one side of the chest; and in extreme cases there is no movement at all in the region of the cavity. That symmetrical movements may coexist with extensive disorganisation or solidification of one lung is contrary to the opinion of many persons. It may be explained by the fact of our having so much spare lung. It has been found by experiment that 310 cubic inches of air could be forced into the lungs taken from a man with a healthy chest (height, 5 feet 4 inches; weight, 107 lbs.; vital capacity, 198 cubic inches), the absolute capacity of whose thorax at death, was 245 cubic inches: therefore there was spare lung for more than 100 cubic inches — a space which he could not command during life. May it not be possible that when a part of the lung is consolidated or disabled, this spare portion may come more completely into use, and allow of the symmetrical movement?

(c) *Of reversed breathing movements.* — A man's breathing may be costal or abdominal for a month, a week, a day, an hour, a minute, and change again, — every possible alternation may occur. This may take place with or without a cavity in the lungs, with or without phthisis pulmonalis, as if a specific motion drew in air to certain parts of the lungs to excite some local change of condition. Although costal respiration is maintained at a greater expense of vital force, yet we see when the vital power is fast ebbing the respiration is always costal, and the last breath is a deep costal inspiration followed by the last expiration.

(d) *Of massive breathing movements.* — Massive breathing is a marked feature of the presence of emphysema in the lungs. There is a total absence of that undulating, rolling, and consecutive motion of the ribs. The breathing is always costal, though it may be conjoined with abdominal breathing, and the ribs are elevated *in the mass*, sometimes together with the shoulders clavicle and scapula. Massive costal breathing is indicative of emphysema of the lungs or pneumothorax. In all other forms of dyspnœa the undulating movement is more or less present, though limited.

(e) *Of interrupted breathing movements.* — In those diseases termed "*nervous*," particularly in young women, the breathing, especially the expiration, is sometimes interrupted and jerking. This appears to be merely a functional derangement; it may sound to the ear like deficient respiration, for the intensity of the "murmur" is generally diminished, as if the jerking "eased away" the expiring air. This is sometimes the case in men. It is very seldom combined with organic disease of the lungs.

(f) *Of partial breathing movements.* — By this we mean independent movement of certain ribs, or of some two or three of the respiratory regions. All the ribs may move as in emphysematous breathing, or none of them may move, or the lower, the upper, or the intermediate set may maintain the respiratory function.

Andral observes, "The partial immobility of the ribs is not without interest in a physiological point of view. Does not this fact prove that, in inspiration, the ribs can move independently of each other, and that they have not merely a common movement? If," says he, "as we have often seen in phthisical patients, the lower ribs can still move when the upper ones remain motionless, it proves that independently of the action of the scaleni, the intercostal muscles are capable of taking, an active part in the act of respiration."* In this way respiration may be separately carried on by any of the twelve costal regions. We have seen a man ill of rheumatism, lying on his back, breathe solely with the diaphragm, and not present the slightest motion of any one of the ribs. And we have seen the contrary, viz., costal breathing, without the slightest movement of the diaphragm. They can act quite independently of each other.

(g) *Of quick and slow breathing movements.* — Not only thoracic disease, but most illnesses, particularly febrile conditions, quicken the respiration. In health the number of respirations average twenty per minute (Table G G), and it has been found that in 244 phthisical cases (males), the average number was from twenty-four to twenty-eight per minute (sitting) (Table I I), the highest number was forty-four per minute. There is every reason to believe that the chemical *quality* of expired air is the same whether we are in health or in advanced disease, though our requirements at these two times may be very different; just as the quality of smoke from a fire is the same whether it burns briskly or slowly. — The quality is constant, and the required modifications are obtained by the difference of quantity in a given time. Quick breathing is short, and slow breathing is long, respiration. The natural time of breathing may change by habit. We have seen a man in health, whose ordinary respirations were six per minute. This extraordinary slowness was induced by an attack of asthma, during which attack (lasting about six years), his character of breathing changed from eighteen short, to six long and deep, respirations per minute; though the asthma entirely left him the character of the respiration remained as first changed by the dyspnœa. In this case the return of eighteen respirations per minute, would be to him the rapid respiration of fever, although formerly the respiration of health. Time and volume, in respiration, are the great modifiers of the energy of aëration.

(h) *Irregular breathing.* — Irregular breathing movements are less common when organic disease is present. A nervous person, as well as a phthisical person, may have every form of irregular breathing, but in the phthisical person the change is less frequent, and is probably due to some change in the disease; in the nervous person the change is frequent, sometimes once or twice during an examination of the chest, Nervous breathing is generally well marked in hysteria.

(i) *Double breathing.*—By this is meant costal and diaphragmatic breathing synchronous with each other; this is not uncommon in severe cases of emphysema, when the mobility of the ribs is much diminished. It is frequently met with in phthisis pulmonalis; — in ninety-one cases out of 233. We have no voluntary power to command this form of breathing in health. It is to be looked upon as a serious modification of respiration. All the modifications of the respiratory movements, induced by disease, may return to healthy breathing again, if the derangement has not been kept up too long. As a general rule, the respiratory movements become natural soon after restoration of the diseased parts to health.

Of the number of respirations in a given time. — The ordinary respirations should be counted without the individual being conscious of the observation; otherwise they become disturbed in number, and sometimes in character.

Table G G.—Number of Respirations per Minute (sitting) in 1897 males.

Respirations per minute.	Number of cases.
From 9 to 16	79
16	239
17	105
18	195
19	74
20	561
21	129
22	143
23	42
24	243
24 to 40	87

Out of 1897 cases, 1731 of them breathed from sixteen to twenty-four times, and nearly one-third of them twenty times a minute.

The mean *relative velocity* of *the breathing and the pulse* is about one respiration to four pulsations of the heart (twenty to eighty), and the variation in health in the number of respirations is from sixteen to twenty-four, and of the pulse from sixty-four to eighty-eight per minute.

Table H H.—Relation between the Respiration and the Pulse (sitting) 1407 males.

Number of Respirations per Minute.	Pulse.	Number of Cases.
16	64	218
17	82	102
18	70	176
20	82	546
22	83	135
24	88	230

From Table I I, phthisis pulmonalis increases the velocity of the breathing movements from twenty (the healthy mean) to twenty-eight, and cases are numerous up to thirty-six respirations per minute.

* Andral, Clinique Médicale, tom. iv. 3d ed. 8vo. Paris, 1804.

TABLE II. — Number of Respirations, of 255 Phthisical Patients, per Minute (sitting).

Respirations per Minute.	Number of Cases.		
12 to 14	4	4	21
14 „ 16	0		
16 „ 18	13	17	
18 „ 20	4		
20 „ 22	44	55	110
22 „ 24	11		
24 „ 26	49	55	
26 „ 28	6		
28 „ 30	47	48	90
30 „ 32	1		
32 „ 34	39	42	
34 „ 36	3		
36 „ 38	16	17	34
38 „ 40	1		
40 „ 42	1	17	
42 „ 44	17		
	*		

A sudden *change in atmospheric pressure* affects the number of breathing movements in a given time. We found the following limited but sudden increase of atmospheric pressure increase them as follows. In South-Hetton coal-mine in the county of Durham, — Depth of the mine 1488 feet.

	Barom.	Thermom.
At the level of the sea	28·72	39°
At the bottom of the mine	30·26	49°
Difference	1·54	10°

The additional pressure of the $\frac{1}{20}$ of an atmosphere increased the ordinary breathing from one to three times per minute.

This difference was purely the effect of pressure, and not that of fatigue or mental emotion. It might only be temporary. Aëronauts inform us that diminished pressure increases the number of respirations; but with them there is this difference, that with diminished pressure there is a sensation of a want of air. When the barometer is *low* we feel lassitude, and call the "day heavy," when in truth the air is lighter, and we ourselves are heavier; when the barometer is high, we generally experience an indescribable sensation of pleasure — the vital energies seem doubled. With a sudden and considerable fall of the barometer there is a transient plethora. The blood-vessels become distended, owing to which, together with certain hygrometric changes in the air, we feel listless, and the least exertion produces perspiration. Duhamel observed that, in the month of December, 1747, the barometer in less than two days fell $1\frac{1}{3}$ in., producing a change of pressure on the body of a man, of 1400 lbs.; this he observes was accompanied with many sudden deaths. It is evident that with an increased pressure we get more air into the lungs with a given mobility; for, *cæteris paribus*, air, with the barometer at 30 in. must be more dense than the same air with the barometer at 29 in. In the mine in question, we experienced a sensation of lightness and vigour. The number of respirations are always increased when there is a preternatural increase in the temperature of the body.

TABLE KK. — Effect of increased Atmospheric Pressure on the "ordinary" Respirations upon six healthy men.

	ON THE SURFACE.		IN THE MINE.	
	Pulse.	Respirations.	Pulse.	Respirations.
M. P.	56	15	50	16
— S.	98	20	98	24
— H.	72	16	68	19
— L.	90	14	88	15
— W.	88	18 5	93	22
— T.	85	18	100	20
Mean -	83	16·9	84·3	19·3

OF THE SOUNDS OF RESPIRATION. — The breaking up of the air into minute streams was discovered by Laennec to produce certain sounds, named "breathing sounds:" which sounds are now made available in detecting organic disease in the lungs. As the air penetrates the lungs, it is divided and subdivided until it enters the minute air vesicles. The air passes, 1st, through the trachea, producing "tracheal sounds," — a hollow rough blowing; 2nd, through the next division of vessels (bronchial), producing "bronchial sounds," less hollow and termed "whiffing or tubular;" and, 3rd, into the air vesicles, producing "vesicular sound," — a soft, silky murmur like a gentle breeze among the leaves of trees. Dr. Jackson discovered that which Laënnec overlooked: — this murmur is not heard in *expiration*, while the other two sounds are. Hence the expiratory murmur is a morbid sign, and if heard on the left side below the acromial end of the clavicle, is a sure sign of some altered condition of the air tubes, not compatible with a healthy lung. This expiratory murmur may sometimes be heard faintly on the right side, and not be a morbid sound; but if strongly heard there, it is a morbid sign. A question now arises: Why is there a murmuring sound with inspiration and not with expiration? First, let us inquire what is the difference between the inspiratory and the expiratory act? They differ in two ways:

1st. In *Inspiration* the lungs are passive; the chest threatens a vacuum, and the air enters a rarefied space. In *Expiration* the lungs are active; there is no rarefied space; the air is squeezed out into the atmosphere. This does not affect our question.

2dly. In *Inspiration* a volume of air is broken up into smaller and smaller streams. In *Expiration* these small streams are collected up into the original volume by larger and larger streams. This answers the question.

The hollow blowing sound in the trachea is caused by the friction of the air against the sides of the tube. The relation of the friction to the stream is the same whether the air passes into or out of the lungs, therefore the tracheal sounds are equally heard in expiration and in inspiration. But not so in the lungs; here, as the stream of air proceeds it is subdivided, and with every subdivision the friction is increased; so that with every advance of the stream into the substance of the lung the sound is increased, and becoming more and more buried in the substance of the lung is heard as in a continual murmur. In expiration the very contrary happens. The friction is as quickly diminished, until the substance of the lung entirely masks what remains. In the larger vessels when the volume of the returning air becomes great, and the diameter of the tube more uniform, the friction is the same whichever way the air passes, and here tracheal and bronchial expiration are audible, during inspiration as well as expiration. If we take a sheep's lung and inflate it, we hear the inspiratory murmur; let go the air and we do not hear it; but contract part of the lung, say with the edge of a paper knife, and you hear the murmur during the lung's collapsing, showing that by increasing the friction you produce the expiratory murmur.

When any disease thickens or diminishes the diameter of the air tubes, or when one part of the lung is obliterated and another part has to do double work, then the friction is increased, and thus expiratory murmur is a true sign of some change in the minute air tubes of the lungs. Sometimes the breathing murmur is so gentle and the thickness of the muscles so great that we have even in health known the inspiratory murmur quite inaudible.

In organic change of the lung these sounds become changed in their intensity, rhythm, and character. The cause of the change of sound is yet involved in much obscurity; hence some persons have been said to have had tubercular lungs, when such has not been the case; or even extensive cavities, &c., yet time has shown that there never had been cavities. All the morbid true sounds yet require to be verified as to their cause. As we have natural changes in the character of breathing, so are there changes in the sounds of breathing, as follows: —

I. In its Intensity		Strong or exaggerated.
		Feeble.
		Absent or suppressed.
II. In its Rhythm	1. Frequency	Quick.
		Slow.
		Jerking or interrupted.
	2. Duration	Long.
		Short.
		Expiration prolonged.
III. In its Character		Harsh.
		Bronchial or tubular.
		Cavernous.
		Amphoric.

When there is fluid or disorganisation in the substance of the lung, there are certain cracklings, crepitations, and gurglings, causing certain other sounds not included in the above list. Unfortunately authors differ in the application of the names for these sounds. They may be all classed under two heads, the dry and the moist, whether the tubes be large or small in which the sounds are produced.

For the Bibliography see that of art. "Resfiration," p. 366.

(*J. Hutchinson.*)

THYMUS GLAND.—(French, *Le thymus;* Italian, *Timo;* German, *Die Brustdruse;* Lat., *Thymus;* Greek, θυμος.)—It is proposed in this article to adopt the following arrangement: First, to treat of the gland as it exists in the human subject, comprehending its ordinary and structural anatomy, and its development. Secondly, to give a sketch of the comparative anatomical history of the organ. Thirdly, to treat of its physiology. Fourthly, to mention what has been observed of morbid changes occurring in it.

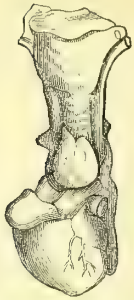
Human Anatomy. — Sir A. Cooper's description of the gland in the human subject is as follows: — "This gland is formed of a thoracic and cervical portion on each side. The former is situated in the anterior mediastinum, and the latter is placed in the neck, just above the first bone of the sternum, and behind the sterno-hyoidei and sterno-thyroidei muscles." "Between two and three months of fœtal life, as will be seen in the plate (*fig.* 717.), it is so

Fig. 717.

The thymus, heart, larynx, &c., of the human fœtus at rather more than two months. (*After Sir A. Cooper.*)

small as to be but just perceptible. At three months (*fig.* 718.) its increase is in proportion to the relative magnitude of the fœtus, and thus it continues to grow gradually and equally (*fig.* 719.) to the seventh month, when it enlarges out of proportion to its former growth. At eight months it is large, but at the ninth

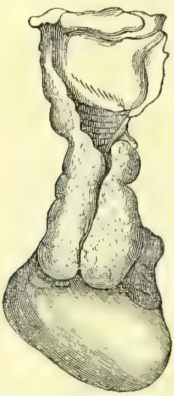
Fig. 718.



Thymus, &c., of human fœtus at third month. (*After Sir A. Cooper.*)

month (*fig.* 720.) has undergone a sudden change, becomes of great size, and is said to weigh half an ounce, from which circumstance, however, on account of the cavities which it

Fig. 719.

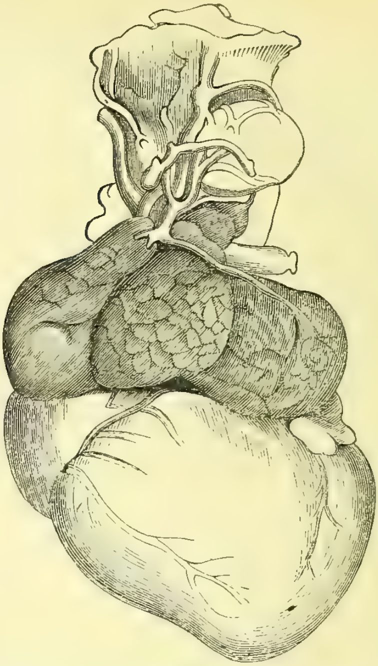


Thymus, &c., of human fœtus at fifth month. (*After Sir A. Cooper.*)

contains, and the varieties to which it is subject, no judgment of its bulk can be formed. It increases after birth, and continues large to the first year, when it slowly disappears to the time of puberty; and in after age it ceases to have cavities, and becomes a body of very small dimensions."

He next notices the following varieties in configuration :—" Although the gland is usually double, and the one side united to the other by cellular membrane only, yet it sometimes happens that a third thoracic lobe exists, which appears to join one lobe with the other, but which allows, under a careful dissection, of their being separated. There are also two other varieties I have seen; the first is the vena innominata passing through the gland, and the second, the same vein placed anteriorly to the cervical lobes. Indeed, I scarcely find two organs alike in form ; sometimes they are round, whilst others are of great length, and are so thin that the serpentine disposition of their lobes may be seen without dissection. The left gland is often larger than the right; but even in this respect so much variety is observable, that it appears if the bulk of the

Fig. 720.



Thymus, &c., of human fœtus at ninth month. (*After Sir A. Cooper.*)

whole be the same, that it is of little importance which may be of the greater magnitude, the right or left gland, as its secretion will be equally abundant."

The *relative situation* of the thymus gland to the adjacent parts is described as follows: —" In cutting through the sternum in its long axis, and then separating its two lateral portions, so as to give a good view of the mediastinum, the thymus gland appears situated behind the first and part of the second bone of the sternum; and posteriorly to the origins of the sterno-hyoidei and sterno-thyroidei muscles. It reaches more than half way down the sternum at birth, viz. to the fourth rib, and extends from thence into the neck near to the thyroid gland. It is connected to the sternum and origins of the sterno-hyoidei and sterno-thyroidei muscles by cellular tissue; it adheres strongly, by a coarse cellular membrane, to the pericardium; anteriorly and laterally the internal mammary arteries and veins take their course. The reflection of the pleura descending from the cartilages of the ribs on each side, and continued to the fore part of the pericardium forming the anterior mediastinum, makes its lateral boundaries, and separates it from the lungs; posteriorly it rests upon the vena innominata, and upon the fascia of the thorax, which descends from the sternum and first rib to the curvature of the aorta, and to the three large vessels which spring from it." " Such, then, is the relative situation of the gland in the chest. In the dissection of the cervical portion of the thymus, the platysma myoides and external jugular vein are first turned aside, and the origins of the sterno-mastoidei muscles are raised; when this has been accomplished, the sterno-hyoidei appear covering and passing over the thymus gland. The sterno-thyroidei muscles . . . cover this organ anteriorly; but when they are removed, the cervical portions of the thymus are seen on the anterior and lateral parts of the trachea, and just below the thyroid gland, where it passes on the fascia on the fore part of the air tube, and unites with the larynx by ligament."

"The internal jugular veins are placed anteriorly and laterally to the cervical portion, and the carotid arteries, with the par vagum, appear more externally."

"The first bone of the sternum and sternal ends of the clavicle cover the junction of the cervical with the thoracic portion of this gland."

"In many of the subjects which I have examined, the cervical portion of the thymus passes higher upon the right than on the left side, and I have generally seen it joined by a ligament to the larynx, and by vessels to the thyroid gland."

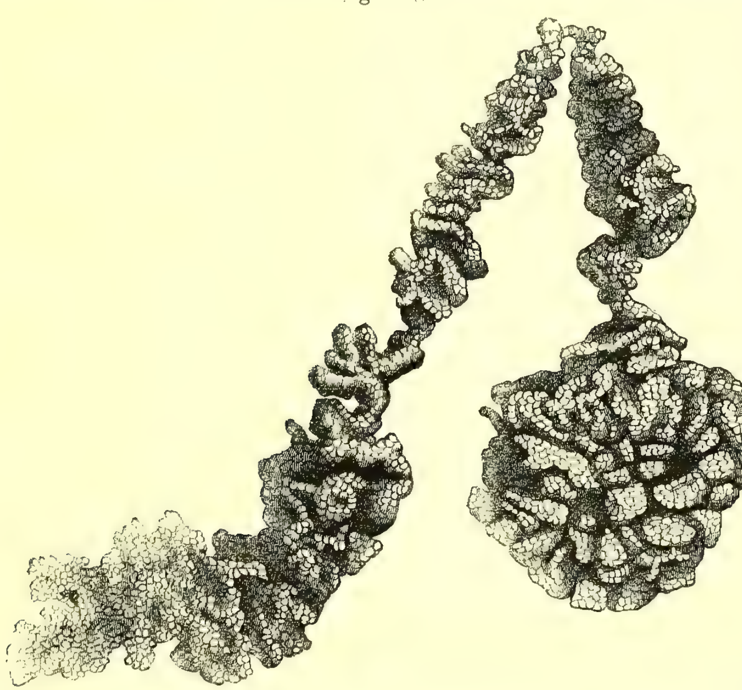
In a human fœtus, at about the fourth-and-a-half month, I found the thymus consisting of two lateral portions, of which the right was the larger (in another of similar age the left was); this portion extended downward, lying upon the pericardium, as far as opposite the right auricular appendix, and reached upwards only to the left brachio-cephalic vein, which it did not cross; the left extended downwards, over the pericardium, to a point opposite the middle of the trunk of the pulmonary artery, and passed up, lying upon the vena transversa, and afterwards upon the side of the trachea, between it and the common carotid, till it arrived at the level of the bifurcation of the arteria innominata.

The appearance of the gland in the fœtus about the middle of utero-gestation is precisely similar to that of the salivary gland in the same; it is beautifully lobulated, and surrounded by an atmosphere of nascent areolar tissue. In the more perfectly formed condition it is surrounded by an envelope of coarse cellular membrane, which penetrates the intervals of its larger divisions, unites the right and left portions together, and forms a general envelope, by which it is connected to the surrounding parts.

In examining the *structure* of the thymus, we are conducted by two eminent guides to conclusions almost identical, though by different modes of proceeding. This coincidence is of great value, and we can scarcely entertain a moment's doubt of its being founded on real truth; it may therefore be well to notice separately the modes of investigation above referred to.

Sir A. Cooper, by skilful manipulation, succeeded in unravelling the gland, and showed each lateral part to be composed of a

Fig. 721.



The right and left thymus gland injected with wax and partially unravelled. In one are seen the rope, the lobes, and the cells, in the other the communication between the thoracic and cervical portions. (*After Sir A. Cooper.*)

rope, on which the lobes and lobuli are set somewhat like the beads on the string of a necklace (*fig.* 721.). By injecting also the glandular cavities with some fluid, as alcohol, capable of hardening the tissue, or with coloured gelatine, which sets and permanently distends them, he demonstrated the existence of a central cavity or reservoir, communicating with the glandular cavities by orifices leading into pouches situated at the roots of the lobes (*fig.* 722.). The central cavity forms a

Fig. 722.

Section of thymus showing the reservoir, cells, and pouches. (After Sir A. Cooper.)

general communication between the different lobes; it does not maintain a straight course, but passes in a somewhat spiral manner, beginning from the lower part of the thoracic portion, and extending even into the extremity of the cervical part of the gland: its size varies in different parts, being largest near the centre of the thoracic, and least at the communication of the thoracic with the cervical, part of the gland. Sir A. Cooper conceived the reservoirs to be lined by a very vascular mucous membrane of somewhat villous character, but this does not appear in reality to exist.

Such were the principal results obtained by a most skilful and eminent anatomist, with all the appliances and aids that his science could at that day supply; they were truly valuable facts, but not so "luciferous," not so exhibitant of physiological meaning, as those obtained by a subsequent inquirer, who, availing himself of the more penetrating ken of the modern achromatic lens, and seeking rather to learn from the instructive examples which Nature herself sets forth, than from results of his own devising and producing, has both confirmed the conclusions drawn from a less refined scrutiny, and invested them with a more correct bearing and interpretation. I refer, of course, to the admirable researches of Mr. Simon, which I now proceed to detail, respecting the structure of the thymus, as illustrated by its developement.

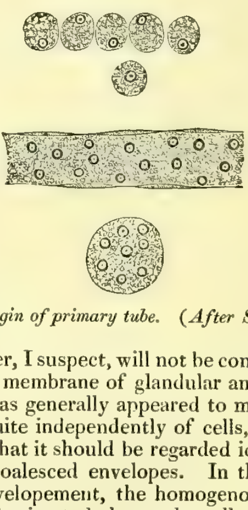
Developement. — The first trace of the organ which has been discovered is in the form of an exceedingly delicate tube, lying along the carotid vessels in the neck, not straight, but wavy at one part, and terminating by closed extremities at both ends (*fig.* 723.). Its wall is formed by a transpa-

Fig. 723.

Primary tube. (After Simon.)

rent homogeneous tunic, marked at regular intervals with elongated thickenings (the remnants probably of the nuclei of primordial cells), and enclosing granular matter, but no distinct corpuscles. There seems some probability that this tubular form, though found to prevail in very early embryos, may not be the really primitive one, but that a linear series of cells is first developed, which are afterwards blended together by fusion, so as to constitute a tube (see *fig.* 724.); this opi-

Fig. 724.



Supposed origin of primary tube. (After Simon.)

nion however, I suspect, will not be confirmed; the limitary membrane of glandular and other structures has generally appeared to me to be produced quite independently of cells, so far, at least, as that it should be regarded identical with their coalesced envelopes. In the next stage of developement, the homogenous wall of the tube begins to bulge, and swell out into vesicular cavities, which at first have wide communications with the central canal or tube, and are quite sessile, but afterwards become attached by short and rather narrow pedicles (*figs.* 725. and 726.). This budding

Fig. 725.

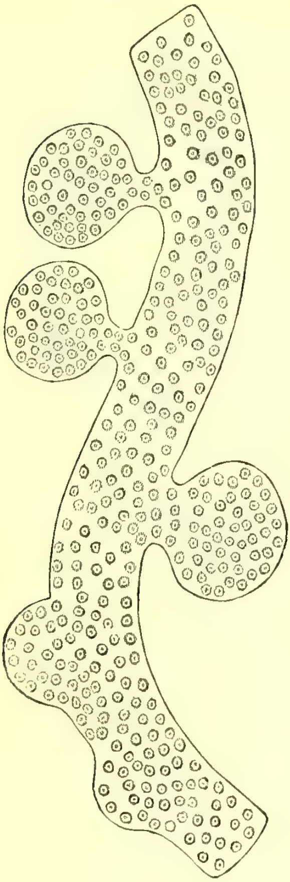
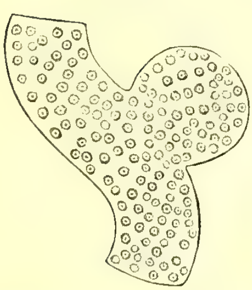


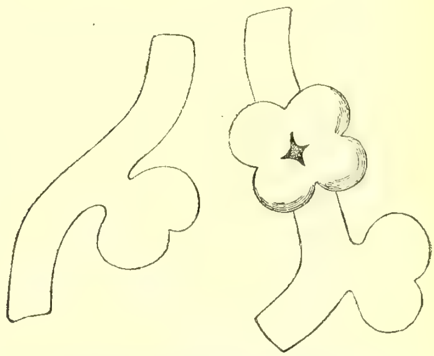
Fig. 726.



Second stage of developement of primary tube forming follicles. (*After Simon.*)

out of the primary tube does not occur simultaneously at every part, or uniformly, but chiefly at those situations which are ultimately to attain the largest size; thus in the fœtal calf we find tolerably well developed bulgings of the primary tube opposite the angle of the jaw, the upper part of the trachea, and the pericardium, while the intervening portions have smooth and undulated margins; and it is just the parts of the gland corresponding to the above points, which ultimately attain the greatest magnitude. The third stage of developement consists in the ramification of the follicles which have budded out from the central cavity; — they do not usually elongate much, before they throw off fresh offsets, and these are completely sessile, so that they have the appearance of vesicles or imperfect spheres grouped together: the mode in which the primary offset divides is either dichotomous or quaternary (*figs.* 727. and 728.), probably also often with some degree of irregularity and inequality in the size of contiguous offsets. By the extension

Figs. 727, 728.



Third stage of developement.
Ramification of follicles by dichotomous and quaternary division. (*After Simon.*)

of this follicular growth to all parts of the primary tube, and by successive lateral ramifications, occurring, as we have seen, to a greater extent in some parts than in others, the gland attains its mature size and complex structure. In this state however it consists, in very great measure, of vesicular cavities, which cluster around and completely obscure the primary tube from which they have originated; yet this primary tube or reservoir does exist, and is capable, as we have seen, of being demonstrated, so that the term which Mr. Simon has proposed, as expressing the type of the mature structure, viz. tubulo-vescicular, is sufficiently correct (*fig.* 729.). Two varieties have been observed in the second stage of the process; one is, that "the tube sometimes bulges uniformly in its whole circumference for some extent, forming a very distinct ampulla;" the other, "that in parts where there are yet no bulgings, it is sometimes flexuous, or even contorted."

The observations now detailed respecting the progressive developement of the thymus, are so important in the elucidation of its structure, that I thought it very desirable to repeat them, if possible, and confirm their accuracy by independent testimony. I have not, however, been able to procure a fœtus at a sufficiently early period to discover the primary tube of the thymus, with its smooth

Fig. 729.

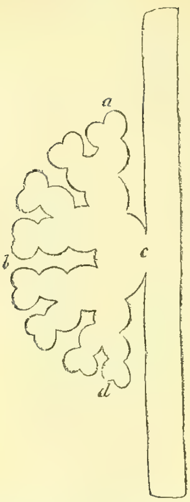


Diagram of fully developed thymus.
Showing how the primary central tube is covered and concealed by the lateral developements, each of which constitutes a conical mass, *a, b, c, d,* with a very wide base. (*After Simon.*)

Fig. 730.

Extremity of cervical portion of thymus from embryonic sheep. 2—3 in. long.
The end of the tube is closed, the central cavity is larger, the walls present numerous follicular protrusions of irregular size and form. Towards the middle the follicles are very much more developed.

unbulging wall, but I have seen it distinctly at a period somewhat later, when the process of lateral extension had but recently commenced. This was in the embryo of a sheep, not more than two inches long, where the thymic cavities were bounded by a well-marked limitary membrane, and filled with nuclei. At the extremity of the cervical portion, the developement of bulging offsets was much less advanced than towards the middle of the gland, so that here the central tube was very apparent, terminating by a closed extremity, and having its margins rendered irregular and wavy by the vesicles which had begun to rise from it (*fig.* 730.). The developing organ was formed in a nidus of homogeneo-fibrous tissue, interspersed with nuclei, which was seen stretching across between the prominent convexities of the bulgings. At the end of the cervical portion this tissue was more abundant, and there was seen running into it a prolongation of the central cavity, which appeared exactly like a short tube, pushing on in a straight direction, and not expanding nto a vesicular cavity. In a young chicken the condition of the thymus was very similar, and the central cavity was larger than the small lateral offsets. These details, though incomplete, leave scarcely a shadow of doubt that Mr. Simon's account is perfectly correct, that the central cavity is the primary part from which the vesicular offsets successively develope themselves. This central cavity may, I am inclined to believe, in some cases disappear more or less completely; at least, in an embryonic sheep, three inches long, it not only bore a smaller proportion to the multiplied offsets, but its wall no longer exhibited the investing limitary tissue, and it seemed as if it were in some measure diminishing, and losing its original distinctness. From what I have seen in the sheep, I should be led to think that the cervical and thoracic portions of the thymus had, in that animal at least, distinct primary tubes as centres of developement, so completely independent have the two parts seemed to be of each other.

Mature structure of the gland. — The results of minute scrutiny into the structure of the fully-developed thymus, accord well with those arrived at by other modes of inquiry. Its surface, when freed from investing areolar tissue, exhibits, though in a rather coarser manner, the minutely-divided appearance so characteristic of the conglomerate glands, and this is especially evident when fat cells have formed in the interstices of the lobules, patterning the surface over with a network of white streaks. In a thin section taken from the gland and prepared for the microscope, the outlines of the vesicular cavities are readily seen; they are much larger than those of the salivary glands, and vary very much in size; in a human fœtus, at about the mid-period, they averaged $\frac{1}{48}$ inch, in a calf about $\frac{1}{28}$ inch, in a young guinea-pig they varied from $\frac{1}{42}$ to $\frac{1}{18}$ inch. Their form is oval or spherical, their outline distinct for about two-thirds of their circumference, but in the remaining part blended with adjacent ones, so that there is never seen any thing resembling a detached and closed vesicle. The sharp definition of the outline by a clear dark line, gives full assurance of the presence of an investing limitary or basement membrane; this constitutes a general envelope, forming the boundary of each of the glandular cavities, surrounding, therefore, the whole mass, but nowhere prolonged into an efferent canal, through which the contents might escape. In structure it is truly homogeneous, that is, considered *per se*, but as it is closely invested by a very thin layer of areolar tissue on its exterior, it has sometimes a kind of fibrous, striated, aspect. In all respects it closely resembles the basement tissue of other glands, and, as in them, I have never been able to perceive in it anything corresponding to the germinal centres of Mr. Goodsir.

The *contents* of the thymic cavities next demand our attention. They consist almost entirely of corpuscles, very closely resembling (in fact identical with) the nuclei of glandular cells; the only difference which the most careful scrutiny can detect between them, I believe, is this, that they present more numerous nucleoli than the nuclei of gland cells usually do. I doubt, however, whether even this is constantly the case. Their form is, I think, for the most part spherical; Mr. Simon speaks of them as generally flat and circular, but I have never observed one, if this be their real form, presenting its thin edge to the eye, as blood-discs frequently do. They vary a good deal as to the condition of their interior spots or nucleoli, some contain two or three, some as many as four or five, a few have one only, and some of the smaller none at all, but are filled with a dimly molecular substance. Their surrounding envelope is strong and well defined, as that of nuclei always is. The extreme variations in size of these corpuscles, according to Mr. Simon, are $\frac{1}{2555}$ inch for the largest, and $\frac{1}{5750}$ for the smallest, probably a correct average, for the generality is about $\frac{1}{5-4000}$ inch. Mingled with these I have found in the thymus of a calf, as well as in that of a young guinea-pig, a few larger corpuscles, about double the size of the former, of spherical form, filled either with granular matter alone, or containing also a nucleus or larger vesicular body. I am by no means inclined to regard these as cells formed *upon* the originally-existing nuclei of the cavities, but rather as expansions of the nuclei themselves, with formation of granular matter in their interior.

It is well worthy of remark, that in the fully developed organ, before any appearance of atrophy has taken place, no other contents than those now described are found in the glandular cavities. There is none of the abundant granular material which forms so large a part of the epithelium of most glands, no diffused oily matter, the nuclei aggregated together into dense masses seem to fill the ultimate vesicles completely, and there is no trace of any material which can justly be regarded as the product of secretion.* A strong solution of bichloride of mercury, indeed, coagulates a small quantity of diffused plasma (probably the liquor sanguinis of blood remaining in the capillaries) which adheres irregularly round the neuclei, but its effect on the contents of the thymus is very different from that which it has on the albuminoid epithelium of the true glands. This is a remarkable circumstance, and, as yet, has not, I think, been sufficiently attended to. If we endeavour to interpret it, it would seem to imply that the thymus is not truly a secreting organ, that is, that it does not separate from the blood or elaborate any special product, or in fact any product at all; but that its function is limited to the formation of an apparatus, which conforming closely to the type of secretory glands is yet not endowed with any analogous property.* The centres around which the material of the secretion should be evolved are present in myriads, but no granular substance analogous to that of glandular epithelium is formed around them. It seems, therefore, that in the case of the thymus, the liquor sanguinis exuded from the vascular plexus through the homogeneous tunic simply solidifies into cytoblasts or nuclei, in most other glands a part takes the same organic form, —a certain number of nuclei are formed,— but these then become the centres of a different and more complete action, or are endued with peculiar attractive powers, in virtue of which the materials of the several secretions collect around them in their respective laboratories. Such is the fact microscopic inquiry adduces, and such the interpretation which may be offered of it; let us now turn to chemistry, and inquire whether the view we have just suggested is supported or negatived by the result of analysis. Mr. Simon gives three analyses of the thymus, which, as he states, though performed on the tissue itself, and not on its fluid contents, may fairly be depended on for conveying a sufficiently correct idea of the chemical constitution of the matters contained in its cavities. Now in none of these is there any mention of any special substance which could be regarded as characterizing the secretion, on the contrary, the constituent elements are mere fibrinous, albuminous, or extractive matters and ordinary saline compounds, and there is none of these which might not exist in the blood, and be most readily derived from it. This is, in fact, the conclusion which Mr. Simon adopts; he believes that we may express the nature of the secretion of the thymus as nearly as may be by the formula of Proteine, or denominate it, in physiological language, as simply nutrient matter.

* The contrast in this respect between the thymus and the thyroid is very instructive, in both the limitary membrane forms closed cavities, which in the one are chiefly filled with secretion, in the other with nuclei, the accredited agents of secretory action.

* Whatever may be the nature of the fluid said to be contained in the thymic cavities in which the nuclei float, it is too small in quantity, and too little apparent, to make it necessary to take it into account; certainly it never collects after the manner of a secretion.

Sir A. Cooper describes the *vascular supply* of the thymus as follows: — "With respect to the arteries of this organ, they are principally derived from two sources. Each thoracic portion is supplied by a branch which is sent off by the internal mammary. It enters at the junction of the cervical with the thoracic part, generally on their outer side, but sometimes between the cervical portions, and, descending upon the middle of the gland, divides to supply the spirally disposed lobes. The other principal artery of the thymus is sometimes derived from the superior thyroideal, at others from the inferior thyroideal artery, and, descending upon the lobes of the cervical portion, passes into them, and ultimately anastomoses with the branch from the mammary artery. The thymic arteries may also arise from the trunk of the subclavian, the vertebral, or the carotid artery, or even from the arch of the aorta. The capillary network in which the arteries terminate, is stated by Mr. Simon to be of "the completest description. It is so arranged as to include each individual vesicle within a vascular capsule; the capillaries are closely applied upon the transparent texture (limitary membrane) which bounds the cavities, and so exceedingly dense is their network that the meshes are of even less diameter than the vessels themselves. Every portion of the glandular substance is thus exposed in the completest manner, and at every point of its surface, to the penetration of the fluid ingredients of the blood." "The venæ thymicæ" Sir A. Cooper states "have a different course to the arteries; for although the internal mammary and thyroideal veins receive small branches from the gland, yet the principal veins are those which end in the vena innominata. A considerable vein springs from each thoracic portion, and passes from the posterior surface of this part of the thymus into the vena innominata; having received a branch from the cervical portion, and vessels from the thoracic: it is found near the centre of the gland. A very small vein enters the thyroideal from the cervical portion, and this vein anastomoses with that of the thoracic part."

Respecting the *absorbent vessels* of the thymus very little seems to be known; we may, however, fairly conclude from the analogy of other parts, that they commence by a network of minute vessels, which have no communication whatever with the glandular cavities, and cannot, therefore, serve the purpose of excretory ducts as has been supposed: the glands to which they proceed are those of the anterior mediastinum.

Mr. Simon describes the *nervous supply* of the thymus "as mainly derived from the plexus which surrounds the first part of the subclavian artery, and which has its chief origin from the inferior and middle cervical ganglia. A small twig detaches itself from this sympathetic plexus, just opposite the origin of the internal mammary artery, accompanies that vessel in its course, and, on arriving at the point where the thymic branch arises, sends filaments along it into the substance of the gland. A second source of supply is the cardiac branch of the pneumogastric, which gives on each side a minute filament to the superior part of the gland." "In one instance I have seen a very minute fibril of the descendens noni emerge from the substance of the sterno-thyroid muscle, and reach the cellular investment of the thymus; and I have sometimes seen delicate twigs of the phrenic also detached towards the gland; but in each case the nerve has appeared to restrict its distribution to the surface and coverings of the organ, and has not accompanied any of its vessels."

The exact arrangement of the nervous fibrils, both tubular and sympathetic, in the substance of the gland is yet unknown; but it seems tolerably certain that they accompany the vessels, enlace them with their plexiform divisions, and terminate, in part at least, in a looping manner.

Early development. — The following quotation from Professor Goodsir's paper in the Philos. Transactions, contains his views respecting the development of the thymus and two others of the ductless glands; I am unable from my own observation to confirm or dispute the accuracy of his opinion, but cannot do otherwise than refer to the labours of so distinguished a physiologist.

"That portion of the membrana intermedia which is separated from the rest of the membrane, and included in the body of the embryo by the umbilical constriction, and which has not already been devoted to the formation of the heart, liver, pancreas, and external portion of the intestinal canal, is found massed along the trunks of the primitive venous system, the sides of the arches of the aorta, the terminal portion of that vessel, and the origins of the omphalo-mesenteric arteries. The portions of the membrana intermedia which are last in being converted into special organs, the Wolffian bodies, are the parts which project one on each side of the aorta along the posterior part of the cardinal veins of Rathke, between the intestinal plates and visceral laminæ. The portions of the membrana intermedia, which remain between the upper extremities of the Wolffian bodies and the heart and liver, and which surround the origins of the omphalo-mesenteric arteries, do not become converted into organs of special structure, but retain during life the original constitution of the membrana intermedia of the blastoderma, and increase rapidly in the embryo constituting the supra-renal capsules. That portion of the membrana intermedia which is situated between those two aortic arches the extremities of which become the carotid and subclavian arteries, remains during life as the thyroid body. It receives its blood from the first and second aortic arches by two large trunks on each side, the superior and inferior thyroid arteries. That portion of the membrane which passes in two parts from near the base of the cranium back as far as the ductus Cuvieri and anterior portions of the veins of Rathke, and which are united and concentrated in front of the heart, by passing from behind forwards in harmony with corresponding motions of the neighbouring part, becomes the thymus. The structure of these organs is identical with that of the blastoderma (?). Their probable function, namely, to prepare by the action of their nucleated cells, and to throw into the vascular system a matter necessary for the nutrition of the animal during the period of its active growth, a function which the observations and opinions of the majority of physiologists have assigned to them, is also essentially the same with that of the blastoderma."

Development of Size.—Having now examined the anatomy of the thymus, and traced its development with a view to the exact elucidation of its structure, we have next to follow out the successive periods of its growth, in order to determine whether it be an organ having special relation to fœtal or to extra-uterine life. The former alternative was that to which the older anatomists, and even Sir Astley Cooper, inclined; but the correctness of the latter seems now abundantly established. Meckel, Hewson, Cloquet, and Sir A. Cooper himself, all concur in stating that it continues to grow at least up to the end of the first year after birth; and more recently the evidence accumulated by Mr. Simon from his own observations and those of Hangsted have quite set this important point at rest.

The following details have been selected from the copious table of instances contained in Mr. Simon's essay, they show conclusively that the gland does not attain its greatest size for some time after birth, and that after a variable period it gradually again diminishes. Thus in the dog, at birth the gland weighs 4·75 grs.; from $3\frac{1}{2}$ months to $1\frac{1}{2}$ year after it varies from 360 to 780 grs.; from 3 to 4 years it varies from 150 to 46 grs. In the cat, at birth its weight=$6\frac{1}{2}$ grs.; from 19 to 37 days after it=30 to 44 grs.; 4 to 6 years after=20 to 3 grs. In the human fœtus of 7 months the gland weighed 33 grs.; at 8 months 40 grs.; at birth 84 to 240 grs.; 9 months after, 270 grs.; at 21 years 40 grs. The weight of the thymus is subject to considerable varieties, which probably depend, as Mr. Simon points out, partly on original differences, some individuals having naturally a larger proportion of thymic structure than others; partly also on temporary alterations in the activity of the nutrient processes, as is well exhibited in the effect of over-exertion on the thymus of lambs remarked by Mr. Gulliver; the size of the gland is known also to diminish when the development of the muscular system is promoted, it being found to waste away much more rapidly in young oxen used for draught, than in others not so employed.

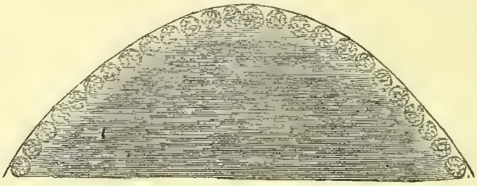
The general conclusion, which the able physiologist from whose work I have drawn so largely adopts, is, I think, truly judicious and accurate; he estimates the period, during which the thymus persists and is active, not so much according to the space of time which has elapsed, but according to the state of the general functions of the frame: if the assimilating processes are active and vigorous, and the supply abundant, and the demand only moderate, the gland will be large and will persist long; if on the contrary the first processes of nutrition are imperfectly supplied, or if great muscular exertion creates a considerable demand, then the thymus ceases earlier to discharge its function and becomes atrophied, because the conditions no longer exist which are favourable to its subsistence. Now it is obvious that in almost every individual these circumstances which so greatly affect the nutrition of the thymus may vary exceedingly, and it is therefore impossible to state an exact numerical age as the period of the highest development of the gland; a physiological age may however with much certainty be named, and it is, as Mr. Simon states, "*the age of early growth.*" The date of the earliest appearance of the thymus in the human fœtus is still little more than matter of conjecture, it has not been positively detected before about the 9th week, when it is quite distinct to the naked eye, consisting of two lateral elongated portions lying parallel to each other on the upper part of the pericardium. Its structure at this time is distinctly tubulo-vesicular, but there is doubtless an earlier stage, when it corresponds exactly to the simple primary tube discovered, as before mentioned, in very early mammalian embryos. The epoch of its entirely vanishing is very variable and uncertain "about puberty it seems in most cases to suffer its chief loss of substance, and to be reduced to a vestigiary form;" but for several years later, even up to 20 or 25, distinct remnants may still be discovered of its structure amid the areolar tissue of the mediastinum.

Comparative Anatomy.—In presenting a sketch of the comparative anatomy of the thymus, I can but follow the elaborate account given by Mr. Simon.

Mammalia. — Among the *Quadrumana* the thymus has, in the more anthropoid Apes, nearly the same general shape and relations as in the human subject, the cervical portion seems to be variously developed in different genera.

Among *Cheiroptera* the gland seems to be persistent in the genera Vespertilio and Galeopithecus, at least so far as anatomical inquiry has yet proceeded; it consists of a thoracic portion embracing the base of the heart, and two cornua ascending parallel to each other on either side of the windpipe In a Bat which I dissected on the 20th of March, and which was then in a wakeful state, I could find no organ which I could positively conclude to be a thymus. On each side, however, of the root of the neck there existed a pretty large yellowish lobulated mass, resembling a good deal the aspect of a conglomerate gland. It consisted of conical lobes which were bounded and defined by a distinct homogeneous membrane exactly resembling the limitary tissue; this was I think continued by reflection from one lobe to another, so as to form a common envelope to all the cavities (*fig.* 731.). The lobular cavities were completely filled by aggregations of celloid particles, which were not manifestly nucleated, nor provided with an envelope, but consisted chiefly of aggregations of oil drops and molecules. Within the thorax at its upper part there was a similar lobulated greyish white mass, resting upon the lower part of

Fig. 731.



Convexity of lobe from oil gland of Bat. A homogeneous membrane encloses a multitude of celloid particles,—the exterior row of which alone is visible, the rest of the mass being quite opaque.

the trachea and the great vessels, and extending round so as to come in contact on each side with the lung ; the structure of this was precisely the same as that of the masses at the root of the neck, with which however it was not continuous. I am much inclined to regard these organs as representatives of the thymus, both from their structure and situation, and because I know not what else they could be ; they are not for a moment to be confounded with the ordinary adipose tissue.

Among *Insectivora* the thymus forms two nearly equal lobes, lying on the base of the heart and origin of the large vessels, with greater vertical than transverse dimensions. In some individuals, at least, it is not persistent throughout life, nor does it appear to be specially developed.

In two Hedgehogs which I dissected, one of which had been in a state of torpor until three days before death, and the other had been active and wakeful for several weeks, I found at either side of the root of the neck two roundish masses almost precisely similar in appearance to those existing in the same situation in the bat, and also two broader and thinner ones lying in the axillæ ; but there was no trace of any such tissue in the thorax. The celloid particles were more loaded with oil than in the bat, especially in the dormant one, and in some parts they were more or less broken up and the oily matter diffused in the cavity. Respecting the existence of a real thymus distinct from these glandular masses I am in doubt, it is not altogether easy to distinguish the structure from that of lymphatic glands several of which lie upon the great vessels at their origin from the heart. However this be it is well worth remarking, that in two hibernating animals belonging to different orders, peculiar organs of precisely similar structure were found ; while, on the other hand, in a mole (an animal which I believe does not hibernate) I could find no unequivocal trace of thymus, nor of the peculiar oil glands which I have described as existing in the bat and hedgehog. This would indicate the existence of the oil gland to have reference to hibernation, but a more extended inquiry on this head is of course necessary before this suggestion could have much claim to be received.

Among *Carnivora* the thymus, except in the cat tribe, where it seems generally to vanish at an early period, is entirely thoracic, resting upon the upper part of the pericardium and the origin of the vessels. When mature "it has considerable thickness and substance in the direction from before backward, and its right and left lobes irregularly overlap each other, so as to render the separation between them indistinct." When the gland becomes attenuated it assumes the form of a triangle, with the apex much prolonged upwards.

The thymus has been found by Mr. Simon in (young) seals, though other anatomists, including Meckel, who, as he says, was little likely to overlook its presence, had not observed its existence ; from this he concludes that it declines and disappears in this family, as in most other mammalia. Its form in the common seal, when present, is nearly symmetrical, consisting of two broad thickish lobes, which prolong themselves upwards to the root of the neck, and abruptly terminate by clubbed extremities, which are deeply grooved in front by the left vena innominata.

In the order of *Marsupialia*, three most eminent anatomists had failed to recognise the existence of a thymus, Mr. Simon has, however, discovered this gland in several instances, it is mostly placed on the pericardium, not reaching into the neck. In the fœtus of the Kangaroo it has a peculiar conformation, being provided with a third, median, lobe projecting outwards between the two others.

Among *Rodents* the thymus differs in shape in the various genera. It consists in the rat of two elongated parallel lobes, reaching from the base of the heart to the root of the neck. In the hare it is much thicker, but still only extends to the root of the neck. In the *hibernating* rodents the thymus is believed to undergo at the approach of winter a remarkable alteration, apparently as a preparation for the long sleep of that season. Tiedemann describes in a Marmot, which he examined in the month of November while in a state of torpor, the gland as "filling the whole of the anterior and posterior mediastina, extending along the great vessels of the neck to the vicinity of the lower jaw, spreading itself out above the clavicles on each side of the neck, and even passing behind the clavicles and pectoral muscles into the axillary spaces." Mr. Simon in his dissections of the same family finds the masses described by Tiedemann, as existing in the anterior and posterior mediastina, but not those in the neck, and states from microscopic examination the remarkable fact, that they all consisted of aggregations of fat vesicles. I do not gather clearly from his description whether these fat cells were surrounded by a limitary membrane, preserving the form of the thymic cavities, in all the situations where the fat masses are mentioned as existing; *i. e.* whether all this fatty tissue was actually developed from the thymus, or a mere accumulation in the ordinary way: nor does Mr. Simon state whether the specimens he examined were in a state of torpor at the time of their death or not. I confess I should wish to have further evidence concerning the accumulations of fat in the marmot's thymus.—I have never seen a really nucleated fat cell, nor have I ever observed any approach to such a development of nuclei. Tiedemann's description indicates so strongly a great difference between the conditions of the masses in question at the commencement of winter and in the summer, that it seems to me quite necessary that a comparative examination of their minute structure at both periods should be undertaken before the question of their relation to the thymus can be decided.

In *Edentata* the thymus is principally thoracic, the Sloth and Armadillo present small cervical prolongations connected to the larger mass by very slender strips.

In *Monotremata* a thymus is found resting on the origin of the great vessels, and scarcely extending into the neck.

Among *Pachydermata* there are marked differences in the form and development of the thymus. A fœtal Elephant presented a flat mass resting on the upper two-thirds of the pericardium, and sending upwards a short prolongation from its right lobe. In a Peccary the cervical portions were of great length, not only reaching to the angle of the jaw, but folded down again beside the trachea. *Solipeds* have a thymus either entirely thoracic or reaching but a little way into the neck.

Among *Ruminants*, the Calf is usually referred to as exhibiting a thymus, which may serve as a type for the family. The gland presents cervical cornua which are highly developed, reach within the angle of the jaw on each side, and form large complicated masses up to the base of the cranium; below, these prolongations are narrowed, and united in close juxtaposition to form an isthmus, which passes behind the first bone of the sternum, inclines to the left side, and expands into another considerable mass of glandular substance situated on the upper part of the pericardium and covered by the left pleura. In the Reindeer the submaxillary enlargements are absent, and the tracheal are of compensative size. In the Fallow deer, again, the cervical portions are more developed, extending up to the cranium, but not reaching below quite to the pericardium.

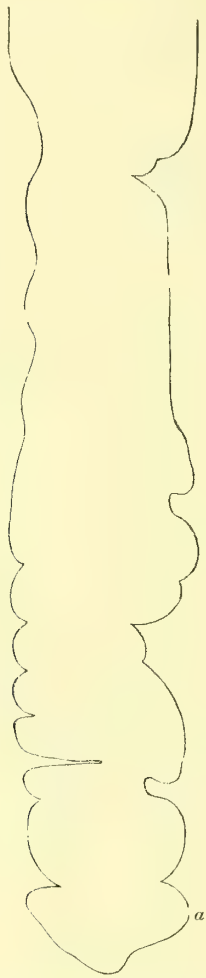
A thymus has been found in several *Cetacea*. In the fœtal Dolphin there are two large median portions, pericardiac and tracheal, with deep seated lateral connecting cornua: in the Mysticete whale there were two pericardiac lobes, from the right one of which a prolongation extended backwards across the arch of the aorta, between the art. innomin. and left carotid till it reached the trachea, and ascended a small distance in front of that tube to terminate in two little cornua: the left lobe was of much smaller size.

Aves.—In the class of birds no organ unequivocally possessing the characteristic structure of a thymus had until lately been shown to exist. Meckel, indeed, described in diving birds an organ which he supposed to be peculiar to them, and which he considered to be the thymus. The microscope, however, in Mr. Simon's hand has demonstrated this organ to be merely a mass of fat, and that, too, even in the youngest specimens; the same observer has succeeded in discovering a real thymus, which corresponds closely in structure with that of mammalia at an early period of development. It is found in the neck of very young birds, lying along the outer side of the superficial cervical vessels, extending from within a line or two of the base of the cranium to just above the inlet of the thorax. It appears as a semi-transparent ampullated tube closed at both extremities, and rather broader at its upper than at its lower part. Under the microscope it is seen to have walls formed by a distinct limitary membrane, and contents consisting of nuclei. The period of its disappearance varies somewhat, being earliest in the tribes of powerful and active flight, but in all occurring very much sooner than in mammalia.

This discovery of Mr. Simon's appeared to me of so much interest, both as regards the existence of the organ in birds, and the further elucidation of its structure which might be expected from the examination of the organ in a lower grade of organized beings, that I was anxious to repeat the observation.

The result was entirely confirmatory of Mr. Simon's description. In a chick about one week old I found on each side of the neck a tube, which appeared ampullated to the naked eye, and which under the microscope exhibited a large central cavity with numerous irregular and slight lateral bulgings (*fig.* 732.). It was filled with imperfect nuclei, and with granular globules, which last were more numerous than usual; there was also a quantity of oily matter in the form of minute drops or molecules. It was remarkable that on the right side the tube was divided into a number of separate portions, which seemed to have become quite isolated from each other; this, I conceive, to have been the commencement of a process of degeneration, an idea which seems also favoured by the existence of a quantity of oily matter as a deposit in the glandular cavities.

Fig. 732.



Lower end of thymic tube from chick one week old. Diameter at *a* 1-15 in.

Reptilia. — In the class of reptiles much uncertainty has prevailed respecting the existence of a thymus gland; it has by some been confounded with the thyroid, by others denied to exist at all. The microscope has again in the same skilful hand cleared away the doubt, and rendered it certain that a true thymus is found in almost all reptiles, distinct from, and independent of, the thyroid. In young specimens of *Chelonia* there is found, extending upwards on each side along the carotid, or between it and the subclavian, an elongated white or yellowish mass, possessing the characteristic thymic structure, and easily distinguishable by this from the true thyroid, which lies in the median line between the carotids, near their origin. I have repeated Mr. Simon's observation on a tortoise, said to be about a year old, and found in the situation he indicates an organ, which, though having to the naked eye somewhat the appearance of fat, is shown by the microscope to have the characteristic structure of a thymus. The lateral cavities are considerably more developed than in the brid, they are of very various size and somewhat irregular, bounded by a distinct limitary membrane, and filled with well formed nuclei, togother with a quantity of opaque granular-looking matter consisting of minute oily molecules. In *Emydosauria* the thoracic portions of the thymus are large and of prismatic shape, they meet on the base of the heart, overlapping the thyroid, and thence extend upwards along the carotid vessels to the base of the skull where they terminate; in the lower part of the neck they diminish somewhat in size, but afterwards continue of uniform diameter.

In several *Saurians* (*Lacertidae*, *Geckos*, *Chameleons*) the thymus resembles that just described, save that the pericardiac portion is absent; in adult specimens of others, as Isturius and Scincidæ, no thymus has been detected, but a mass of fat exists just above the base of the heart, which may perhaps result from a transformation of the gland.

In *Ophidia* the thymus observes one undeviating type of arrangement, it is found lying on each side along the carotid, often not strictly symmetrical, its lobes elongated and sometimes broken into two or more pieces. Most serpents possess a peculiar mass of fat which is developed in connection with the thymus, and often obscures or conceals it; in two specimens of rattlesnakes Mr. Simon found this fat body was absent, but is inclined to believe it exists in those which inhabit the temperate latitudes. The thymus of serpents is supposed by Mr. Simon to be persistent, and to undergo transformation into fat.

From the *Batrachian* reptiles it was natural to expect, that in consequence of the remarkable transformation which some of them undergo, and the intermediate condition maintained by others between reptile and piscine life, some important information would be gained respecting the true relation and import of the thymus. So it has proved; for in the Frog only a mass of fat is found existing in the adult animal in the situation of a thoracic thymus, the very young animal, however, presents, in the same situation, true thymic structure, and the evidence of a real transformation of the gland, — not a mere replacement of it by fat,—seems more perfect than in the case of the hibernators before referred to. It was now a point of much interest to determine the condition of the thymus in the fish-like batrachian larva before its transformation had occurred; in none of these was any trace of thymus detected, while in the youngest individuals in whom pulmonary respiration had commenced the "commencement of the organ" was always to be found. Mr. Simon remarks; "The essential step in reptile metamorphosis is a higher developement of the respiratory system: as a part of this process we here find occurring the superaddition of a thymus gland, — its first appearance in the ascending scale of organization." Among the *Perennibranchiata* it is very interesting to observe, that the gland is gradually suppressed in proportion as the respiration becomes more completely aquatic, a thymus is found in the Menopoma, Amphiuma, Axolotl, and Menobranchus, but not in the Siren or Proteus; its position is rather peculiar, it lies in the neck, on each side, along the lateral aspect of the spine, just behind that prolongation of mucous membrane which unites the branchial cavity to the pharynx.

Pisces.—In fishes Mr. Simon has been unable to discover any trace of a thymus, after searching, carefully, in more than twenty genera; this result accords well with the absence of the gland in the fish-like batrachian larva, and with its disappearance in the lowest Perennibranchiata.

The following are the *conclusions* which the eminent physiologist, so often referred to, deduces from a survey of his detailed and elaborate investigation. (1.) The presence of the thymus gland is co-extensive with pulmonary respiration. (2.) Its shape and position are variable and unimportant. (3.) Its size and duration are, generally speaking, in proportion to the habitual or periodical inactivity of the animal. (4.) Where it remains as a persistent organ, it is usually but one of several means for the accumulation of nutritive material; its continuance, under such circumstances is generally accompanied — though in some instances superseded — by a peculiar accessory contrivance, *the fat body*.

PHYSIOLOGY. — The time is now past when an eminent physiologist could declare of the organs usually known as glands without ducts, "that in regard of their intimate structure and physiological meaning, they are all equally and utterly unknown to us." With respect to their structure, it may, I think, be said, that they are as well understood, or perhaps even better than the true glands, being in fact less complex, and their constituent parts less independent. Their physiological meaning, it must be confessed, is still obscure; yet even on this dark part of the demesne of our science light is beginning to break, which we may fairly hope will continue to brighten.

The results afforded by examination of the thymus in the lower animals seem certainly to connect the gland most closely with *pulmonary* organs of respiration, and it would, therefore, seem a natural conclusion, that it subserves some purpose which has to do with the aeration of the blood. It is also found that the size of the gland may vary in a short space of time very considerably, that is, that its contents are capable of being absorbed very quickly, as proved by the fact mentioned by Mr. Gulliver, that in over-driven lambs, the thymus will soon shrink remarkably, and be nearly drained of its contents, but will become as quickly distended again during rest and plentiful nourishment. This seems to imply that the material necessary for the supply of the respiratory process is furnished by the thymus, which thus, in Mr. Simon's words "fulfils its use as a sinking-fund in the service of respiration." The persistence of the gland, moreover, is observed to vary considerably according to the muscular activity of the animal, thus it disappears quickly in young oxen put to the plough, it endures longer in animals of quiet habits than in the restless and energetic beasts of prey, and vanishes at a very early period in the class of birds, while it persists long in that of reptiles. From this it seems to follow, that the use fulfilled by the gland in the service of respiration is more or less superseded when the muscular system is called into a high state of activity, *i.e.* when there is considerable waste of tissue yielding fuel for respiration. In the hibernating animal, where the gland, preparative to the winter sleep, is transformed into a mass of fat, its application to the demands of the respirtory process seems scarcely doubtful, as the chemical nature of the contents of its cavities is then peculiarly appropriate to neutaralise the oxydising agency of the air.

Probable, however, as these views may appear, they have been confronted by the following weighty objections. An able physiologist, in the Brit. and Foreign Med. Review, observes, that the condition of young, rapidly growing animals, and that of hibernating animals, are rather opposite than parellel, that whereas in the latter, the waste of the tissues is reduced to a minimum, in the former it is certainly greater than in the adult, so that there can be no deficiency of effete material to feed the respiratory furnace. The demand in the young creature is for plastic materials, out of which the rapidly growing and rapidly changing structures may be built up and renewed. "On the other hand, in the hibernating animals all the nutritive actions are at zero, and the respiration for a long period is entirely dependent on the stores of fatty matter which have previously been set apart from the food. The demand is here for *combustible materials*."

The writer then observes, that the chemical nature of the contents of the thymus correspond so exactly at the two periods of active growth and hibernation to the kind of demand which must then exist in the system, that he conceives it more probable that the use of the gland at these times is different; in the one slowly yielding up its hydro-carbonous contents to supply fuel to the respiratory process, in the other performing the principal part in elaborating, by means of its myriad nuclei, fibrine from albumen, the plastic from the non-plastic element. "As the demand for plastic material becomes less energetic the thymus diminishes in size and disappears, the production of plastic matter within the absorbent and sanguiferous vessels being then sufficient for the wants of the system. Or if the organ remains," its structure "and the nature of its *function* changes, and it cannot be deemed unreasonable to suppose that its *use* in the system should change also. In fact, that its use should be the same in the two cases, where its functions are so different, appears to us a very improbable supposition." Consonant with the above view is that of Mr. Paget, who remarks in his Report, that the fatty transformation of the thymus is an atrophy or degeneration of the gland, "analogous to that atrophy by diminution or total removal of substance, which takes place once for all in the animals in which the thymus is not persistent. In each case the atrophy is an indication that the necessity for the ordinary acts of the thymus has ceased; but in the hibernants it is, for new circumstances, made to minister to a new purpose, till at the expiration of the winter sleep, and the recommencement of new growth it begins again to be truly developed, and to form the more highly azotized organic compounds which it may restore to the blood for the nutrition of the fresh growing tissues."

On a careful consideration of the theories now noticed (and no other are worthy of any examination), it seems to me, certainly, that the latter is nearest the truth; and that we cannot regard the thymus in the young animal as a mere preparer of material fitted to support the respiration. The following arguments must be allowed to weigh strongly against Mr. Simon's view. (1.) The chemical constitution of the thymus, consisting chiefly of proteine and not of fatty matters, seems by no means to be such as would be best adapted to sustain the supply of combustible material required in respiration. (2.) The office of serving as a reservoir for material to be used in respiration may be attributed with much more probability to the liver*, the construction of which, as also in some measure its position relative to the circulatory system, point it out as peculiarly adapted for the reception of superfluous respirable material from the blood, and equally so for rendering it up again, when the demand again begins to be felt in the circulating current. Of this, the condition of the liver in fish, and generally in all animals, in whom the respiration is of a low type, is sufficient proof. Now as the liver is of greater relative size in the young than in the adult animal, it is not likely that this one of its functions is in any measure discharged by the thymus. (3.) The anatomical constitution of the thymus is very unlike that of an organ which serves as a reservoir of respirable matter. For this purpose we should expect to find a fluid stored up in cavities, such as the oil of the fat vesicles, or the oleo-biliary matter which collects within the cells of the liver; the anatomical elements, however, of the thymus are totally different, being mere nuclei, with no trace even of commencing cell development, in fact, just that part of a glandular apparatus which is *not the secretion*, however important a part it may play in the elaboration of it. (4.) The transformation of the thymus into fat previous to the winter sleep, concurrently with the formation of other fat masses in the axillæ, indicates, as above shown, very strongly that the gland in its natural state fulfils some purpose different from that to which it is subservient during hibernation. But as there can be no doubt that it undergoes this change for the sake of the respiratory function,—to fit itself for supplying those demands during the long period when the waste of the tissues is reduced to a minimum, and no ingesta are taken,—it seems tolerably certain that while the gland continues in its normal unchanged state, its action must be of a different kind, not having special reference to the function to which during hibernation it undoubtedly ministers. The circumstance quoted by Mr. Simon from the writings of Mr. Gulliver, respecting the remarkable shrinking of the thymus in over-driven lambs, cannot be regarded as proving that the contents of its cavities are thus absorbed *solely* for the use of respiration. It is more probable that they are resumed into the blood, which has begun to be impoverished by fasting and exercise, in order that they may go to supply the nutrition of all parts indifferently. With regard to the arguments adduced by Mr. Simon from Comparative Anatomy, to the effect that a thymus has some essential connection with *pulmonary* organs of respiration, I would remark that though it is certainly of weight, yet it cannot be regarded as proving absolutely that the two organs are co-related in function. It may be that they are only simultaneously developed, — connected together in virtue of some law of organized being which requires their coeval appearance, and yet not intended to minister to a common pupose.* I grant that observing their consentaneous appearance, one should inquire whether they be not essentially linked together in function, but if this be not proved by subsequent inquiry, or *à fortiori*, if it be shown to be unlikely, then the argument arising from their co-development ceases to have much force.

But if we decline accepting the theory proposed by Mr. Simon, are we to close, unconditionally, with the other which has been above expounded, and which is but a modifi-

* I may just briefly mention here the results to which I have been led by a long and careful study of the liver in vertebrata. Its lobules (if it is so divided) are not penetrated by excretory ducts, nor are the secreting cells contained as in most other glands in the cavities of ducts, they lie naked in the interstices of a close plexus of most delicate-walled, capacious, capillaries, from which they readily receive the materials they are intended to act on; and to which they as readily render up their elaborated products when these are called for. The excretory ducts, consisting at their origins almost solely of nuclei, attract into their cavities the oleo-biliary secretion with which they are bathed; probably, however, in so doing altering it to some extent.

* This is perhaps the more probable, seeing that the thymus does not assert its connection with organs of respiration taken generally, but only with a particular modification of them, so that its existence is determined not so much by the *degree* in which the function is fulfilled as by the *mode*. Hence it is absent in the higher fishes and in insects.

cation of a former opinion, that of Cowper and Haller, who regarded the thymus as belonging to the class of conglobate glands. It appears on the whole more consistent with the various facts bearing on the subject which are in our possession, and yet it is by no means proved, and is open to some objections. In the first place, one is inclined to look suspiciously on any hypothesis, which assigns the production of a material almost universally diffused throughout the body to any separate organ, it seems far more truth-like to regard the manufacture of the plastic element (fibrine), as taking place in the blood itself by the agency of the white corpuscles, as Drs. Addison, Williams, and Carpenter, have well nigh demonstrated to be the case. If their view be correct, it becomes still more improbable that the thymic nuclei should be the producers of fibrine, seeing that they are altogether dissimilar in appearance and structure from the white granular corpuscles. Moreover the early disappearance of the thymus in birds, long before the demand for plastic material can have materially diminished, makes it unlikely that in them its function is the elaboration of fibrine. The same observation applies to mammalia though in a less degree; and, generally, I think there can be little doubt that the self-forming, self-sustaining blood, while supplied with an adequate quantity of proper nourishment, is fully capable of evolving within itself all that is requisite for the nutrition of any part of the system.

It seems almost unwise to broach any further speculations respecting this *ignotum quid*, especially after stating objections to the views of others; and yet while ideas are offered as mere suggestions, to serve if they may as aids to the discovery of truth, they are not without utility, since none can say without trial which of these "scintillæ" may kindle the light of truth. From the careful investigations which have been made respecting the age at which the gland attains its highest development, and the conditions which chiefly affect its size and repletion, it certainly appears to be a very exact exponent of the state of the nutrient processes generally,—a delicate barometer of nutrition, as Mr. Simon terms it. Moreover its anatomical constitution, as I have insisted, seems to show that it does not truly secrete, *i. e.* elaborate and separate some peculiar principle from the blood, but that it is a congeries of (nuclear) particles, which can only be regarded as solidified liquor sanguinis, and not in anywise as a true secretion, especially when we remember that in every such fluid the nuclei of the producing cells sooner or later disappear. Chemical analysis, as we have seen, confirms this position; the formula expressing the nature of the contents of the thymic cavities being identical with that of proteine.

Now if one of the organs which belong to the class of ductless glands have for its function to act as a living attractive recipient or reservoir for the blood *en masse*, may not another fulfil its destined purpose by serving as a reservoir for that part of the blood which ministers to nutrition, perhaps for the plastic element of the liquor sanguinis in particular? When such plastic material is in superabundance in the circulating current, a quantity of it passes off, and solidifying in the thymic cavities, assumes that most universal of all organized forms, the form of nuclei.* When there is again a demand for such material, the solidified particles would again liquefy, and re-enter the impoverished blood. It is not difficult to understand that such a function may be most necessary during the period when growth is most active, the supplies of nourishment most frequent, and the waste of the tissues most rapid, but that as the several nutrient processes, both of the assimilative and destructive kind, attain to more steadiness and equilibrium, diminishing somewhat in their intensity and rapidity, but increasing in real strength, firmness, stability, and perfection (one is obliged to use somewhat metaphorical language), it may no longer be requisite, and the organ will therefore undergo a gradual atrophy.

This hypothesis, which is really little else than an expression of the facts above noticed, has been principally suggested by the consideration of the nature of the secretion (so called) of the thymus, wherein it differs absolutely from all other glands, in as much as the nuclei constantly remain in their primitive state, and are not even mingled with granular matter; while it agrees in this respect with another organ of similar kind, the spleen, whose parenchyma consists of similar *bare* nuclei, which exert so far as we know no real secretory action. It is however by no means improbable, that, even if this guess at the use of the thymus be correct, we are yet very far from being fully acquainted with all the reasons why it exists, and why in such a situation, and under such a form. If Mr. Goodsir's account of its origin, from a portion of the blastoderma, with the suprarenal capsules and thyroid, be correct, it is possible that its formation may be demanded by some recondite law of development, in virtue of which the extraction of one organ out of the primitive blastema necessitates, by a kind of compensating action, that another should arise in some sense complementary to it. This idea, originally stated by Treviranus, has been developed very ably and pleasingly by Professor Paget, to whose lectures I refer for a full exposition of it.

Morbid Anatomy. — Not much is known, and probably there is not much to be known, respecting the morbid conditions of the

* I would here direct attention to the remarkable fact, that in all glandular, and in fact in almost all, organs, the nuclei are almost precisely similar in size and appearance, and do not differ from each other in different parts more than individual ones do in the same. Does not this indicate strongly a tendency of liquor sanguinis effused in conditions of healthy nutrition, to assume the form of nuclei, irrespective of the situation or special endowment of the part where it is effused?

thymus. *Absence* of the gland has only been observed in cases of acephalism, where the brain and many other parts are simultaneously deficient, while in cases of anencephalism, where the brain is also wanting wholly, but the general development much more complete, the thymus is present; nothing therefore can be concluded from its absence in cases of extreme monstrosity as Mr. Simon has well observed.

Inflammation of the gland, if it ever happens, is of rare occurrence. Professor Hope, however, refers to a case by Mason, in which an abscess of the thymus is said to have opened into the trachea.

The same author states that Becher and Hangstadt have collected about fifteen examples of persons, of different ages, affected with more or less general *tubercular* disease, in whom the thymus was found involved. " It was for the most part considerably enlarged, very firmly united with surrounding parts, and either converted by tubercular infiltration into a hardened mass, or else partially destroyed by tuberculous softening. In three or four instances calcareous concretions, probably resulting from the retrogression of tubercle, were discovered in the gland."

Haller speaks of the thymus as being frequently affected with *scirrhus* along with the conglobate glands; but though Becher gives an instance on his own authority, and refers to others, there can be no doubt that true malignant disease of the gland is extremely rare. Sir A. Cooper gives a case, in which death was produced by the pressure of an enlarged thymus upon the vena transversa and upon the trachea, probably also upon the vagi nerves; there was severe dyspnœa and œdema of the lower extremities. He considers the disease to have been of the fungoid kind, *i. e. encephaloid.*

Atrophy of the thymus occurs as a normal event; if, however, it should take place long before the usual period, determined, as we have seen, not so much by the lapse of time as by the condition of the system, it must be regarded as morbid. Yet in every such case it is almost certain that the atrophy of the thymus would be but part of a general malady, wherein the nutrition of every organ was greatly impaired.

Hypertrophy of the thymus has attracted more attention, Dr. Kopp having noticed several cases of suddenly fatal dyspnœa occurring in children, in whom the gland was found of large size, concluded that there was some essential connection between the glandular enlargement and the suffocative paroxysms. The fallacy of this opinion has been well pointed out by Mr. Simon and others. I must refer to his work, and that of Professor Hope, for a full account of their arguments, and will only mention two circumstances, which seem to me conclusive upon the point. The first is, that "thymic asthma" may occur with an unnaturally *small* thymus; the second, that when a thymus, enlarged by malignant disease, as in Sir A. Cooper's case, does occasion dyspnœa, it is not sudden and paroxysmal, but constant and exhausting.

For the history of the thymus, and for a copious list of authors who have written upon it, I can do no better than refer to the Historical Introduction to Mr. Simon's essay.

(*C. Handfield Jones.*)

THYROID GLAND. (French, *glande thyroïde;* German, *Die Schilddruse;* Italian, *Tiroidea glandola*; Latin, *Glandula thyroidæa.*) The organ which has received this name is a bilobed glandular body, situated in the human subject in close proximity to the larynx, from the prominent cartilage of which it has probably derived its appellation.

Its *size* varies considerably in different individuals, according to unknown peculiarities. In the female it is generally larger than in man; reversing thus the proportion which obtains between the vocal apparatus in the two sexes, and so far negativing the idea, that the larynx and the thyroid gland are in any wise intimately connected.

The normal *weight* of the thyroid is about one ounce, according to Cruveilhier. Any great excess above this must be regarded as indicating a pathological condition.

Its *form*, as has been said, is bilobed; the lateral lobes being united by a thinner and narrower portion termed the isthmus. It would appear (from the circumstance that variations of form are most frequent in the isthmus, which sometimes is even wanting) that the lateral lobes are the primary parts of the gland, and, in fact, in one entire class (that of birds) the lobes lie entirely separate, one on each side of the trachea. In the human subject they are large and solid, presenting an anterior convex surface, a posterior concave, an external and inferior border which is convex, and runs up to join the superior interior concave border in a pointed cornu, which reaches as far as the origin of the inferior *constrictor pharyngis* from the ala of the thyroid cartilage. From the upper border of the isthmus, or from the adjacent part of one of the lateral lobes, there stretches upwards a narrow strip of glandular tissue, which has been called the pyramid or mesian column, and which may have been sometimes mistaken for a muscle, as Cruveilhier asserts; though it is distinguished perfectly from the so called *levator gland. thyroid.* by Haller. This prolongation sometimes extends to the hyoid bone, but generally not so far, and is subject to numerous modifications of shape and structure. The following list of the various forms which the thyroid may present, is taken from the catalogue of the museum of Guy's Hospital, which Dr. Birkett, the curator, most kindly allowed me to inspect, together with the preparations. 1. Thyroid without an isthmus, but having two mesian columns. 2. Thyroid almost without an isthmus, and having one mesian column. 3. Thyroid with broad isthmus and one mesian column. 4. Thyroid with no isthmus, but having one large mesian column. 5. Thyroid without isthmus, having one column (*right*), and an isolated portion on the left. 6. Thyroid with one lobe only developed, and a little glandular body below the middle of thyroid cartilage. 7. Thyroid gland replaced by a membranous substance, two small portions only remaining. 8. The gland with isthmus and two mesian columns.

It is important to ascertain accurately the *situations and relations* of the thyroid. I give them as they are stated by Cruveilhier, and confirmed by my own observation. The isthmus lies across the first four rings of the trachea, the first not being completely covered.* Its upper margin is about half an inch below the inferior border of the cricoid cartilage: from it the mesian column passes upward, lying upon the crico-thyroid muscle, the thyroid cartilage, and the thyro-hyoid membrane. The lower border of the isthmus is free, and occasionally descends so low, that there is not space between it and the sternum to perform the operation of tracheotomy. Posteriorly, the isthmus is firmly attached to the rings of the trachea by close and dense areolar tissue. The sterno-hyoid and sterno-thyroid muscles overlap the greater part of the isthmus; a small portion, however, in the median line is covered only by deep cervical fascia, and perhaps crossed by some branches of origin or communication of the anterior jugular veins. The lateral lobes, concave posteriorly, embrace, and rest against the sides of, the trachea, the cricoid cartilage, the inferior and lateral parts of the thyroid cartilage, and the lower part of the pharynx and upper part of the œsophagus. "These lobes form, with the connecting isthmus, a half or sometimes three fourths of a canal, which surrounds all these parts. This relation, one of great importance, explains how certain goitres flatten the trachea laterally, hinder deglutition, and finally bring on a real asphyxia from strangulation."† The posterior border of the lateral lobes corresponds to the vertebral column, and rests upon the carotid artery; but, if enlarged, it extends further outward, and lies upon the jugular vein. Both recurrent nerves ascend behind the lateral lobes, and are closely in relation with them as they pass under the lower edge of the inferior constrictor muscle. Anteriorly, the sterno- and omo-hyoid muscles pass in front of the lateral lobes, the sterno-thyroid is stretched as a thin band over their surface, and in cases of considerable hypertrophy may be seen sunk in a deep groove formed in their substance, or, as Cruveilhier states, expanded to a width double or treble its natural size. These muscles separate the thyroideal lobes from the sterno-cleido-mastoid, which, with the mastoid artery and the superficialis descendens on its inner surface, overlaps their greater extent, as it passes backwards and upwards to its cranial attachment. "The superior extremity of each of the lateral lobes terminating in a point, whence the bicorned form which has been attributed to the thyroid body, corresponds on the inside of the carotid artery to the lateral and posterior part of the thyroid cartilage, and extends sometimes even to the neighbourhood of its upper border. The inferior extremity, thick and rounded, descends more or less low in different subjects, and corresponds to the fifth, sixth, or even to the seventh ring of the trachea; it is situated between the trachea and the common carotid artery. By the inferior extremity the inferior thyroid artery reaches the gland." "The superior border is concave, and skirted by the superior thyroid arteries." The inferior is convex, and has branches of the inferior thyroid running along it.

The thyroid gland is of a red or reddish yellow *colour*, of tolerably firm *consistence*, and gives to the touch the sensation of granulations. Cruveilhier, thus describing, proceeds as follows: "This organ presents all the anatomical characters of glands, and, like them, is separated by dissection into glandular grains" (doubtless meaning the acini of Malpighi); "but there is, between these glandular grains and those of ordinary glands, this difference, that in the thyroid gland the glandular grains communicate with each other, while in the others they are independent." He then details the result of mercurial injection, to show that the glandular grains, or granulations, have a vesicular structure, and communicate with each other; this latter statement, however, is certainly erroneous, as we learn from more accurate modes of investigation. The presence of a certain amount of secreted fluid, in the natural condition of the tissue of the thyroid, and the accumulation of a similar material in larger quantities under certain morbid conditions, the eminent French anatomist justly regards as evidence of the thyroid possessing a secreting apparatus; but, at the same time, faithful to the results of accurate dissection, he acknowledges that no excretory duct can be found leading either into the trachea, the ventricles of the larynx, or the foramen cæcum of the tongue, whither earlier observers had, with too nice refinement, sought to trace its course. Far truer and more physiological than such straining after uniformity is the conclusion he adopts: "I think that there exist, in the economy, glands without excretory ducts, such as the thymus, the suprarenal capsules, and the thyroid gland. The liquid produced in the gland is absorbed entirely, and fulfils unknown uses." I have thought it worth while to follow this accurate and trustworthy anatomist through his account of the structure of the thyroid, though it be somewhat antiquated, partly for the sake of the confirmation it affords to the results of a more recondite and powerful analysis, and partly that we may observe how securely we may trust Nature's own teachings, even when they may appear, for a time, contradictory to established doctrines, as doubtless it must

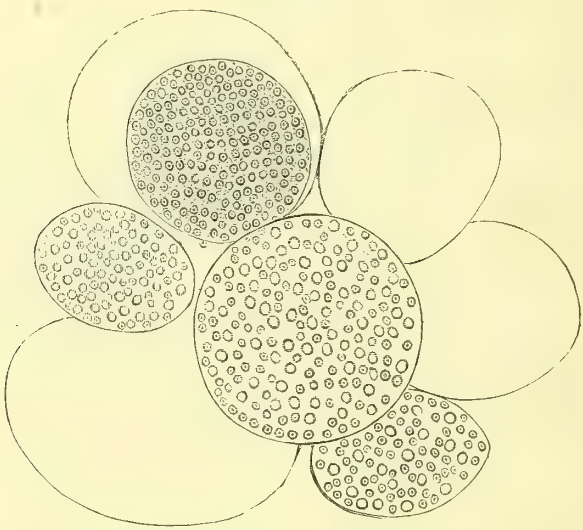
* There is probably some variation in this, according to the varying depth of the isthmus.

† Cruveilhier, Anat. Descr.

once have been considered that a gland should exist unprovided with an efferent duct.

I now proceed to give a more detailed account of the *structure* of the thyroid gland. Its surface is somewhat uneven, — a natural condition which is often greatly exaggerated in hypertrophy of the gland ; it is traversed by several large branches of the nutrient arteries, which ramify over it before they plunge into its substance. A thin fibrous expansion, continuous with the sheath of the cervical vessels on each side, forms a capsule which invests the gland, and from whose inner surface septa dip into the interior, dividing its substance into lobes and lobules much after the manner of a conglomerate gland ; these fibrous septa are often well seen in sections of hypertrophied specimens. A thin slice of the thyroid, examined under a low power of the microscope, displays its constitution very perfectly and readily (*fig.* 733.) It is seen to be made up of closed vesicles, aggregated together in groups of various size by the fibrous expansions just described. The form of these vesicles is primarily spherical ; but many, perhaps the majority, are more or less affected by mutual pressure, being triangular, elongated, ovoid, or oblong. They are all perfectly closed, the wall being formed by an homogeneous limitary membrane, which is easily traced all round, and can never be seen passing off into a neck, or blending with the envelope of an adjacent vesicle. Where a number of vesicles lie closely crowded together, the homogeneous envelopes are of course in contact, or separated only by the interjacent vascular plexus ; but those forming the surface of a group are invested by a thin expansion of fibrous tissue derived from the general capsule. The diameter of the vesicles of the human thyroid I have found to range from $\frac{1}{2000}$ inch to $\frac{1}{85}$

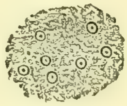
Fig. 733.



A group of vesicles from the thyroid gland of the bullock.
They contain the vesicular epithelium, and that consisting of nuclei and granular matter, in varying proportions.

inch ; in the bullock, from $\frac{1}{2000}$ inch to $\frac{1}{48}$ inch ; the greater number averaging about $\frac{1}{60}$ inch, in this animal as well as in the pig. In the mesian column I found, at least in one instance, that the structure was essentially the same as that of the thyroid itself, only that there was a much greater amount of fibrous stroma, which resembled more nearly ordinary areolar tissue, containing both the white and yellow element.

Fig. 734.



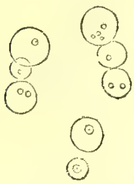
Epithelium from thyroid of bullock.

Fig. 735.

Epithelial particles fro thyroid of rabbit.
Diameter $\frac{1}{2000}$ in.

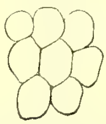
The vesicles are lined internally by an epithelial stratum, consisting usually of nuclei set closely together in a scanty basis substance (*fig.* 734.), which is either feebly granular, or of a somewhat oily aspect. The nuclei are at once recognised by the practised eye as exactly resembling those of the true glands. Their nucleoli are not always visible, and vary very much in number — from one to four or five. The nuclei are, however, always vesicular, bounded by a strongly marked envelope and have a mean diameter of $\frac{1}{3000}$ th inch. It has been observed by Mr. Simon, and I have occasionally had the opportunity of confirming the remark, that the nuclei, instead of remaining in their primitive condition, proceed to the further stage of cell development; this he has noticed both in man and in several of the lower animals. I should say that it is certainly a circumstance of rather rare occurrence; but it is worth remarking, that it may be artificially produced by adding to the specimen some coagulating re-agent, which speedily solidifies a film of albuminous plasma around the nuclei, and thus produces very good imitations of cells. The epithelium of the thyroideal cavities often assumes the form of small vesicles larger than the nuclei (see *figs.* 736, 737, 738.), and easily distinguished

Fig. 736.



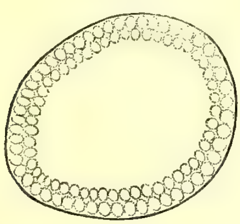
Vesicular epithelium from Human thyroid. Diameter of vesicles, $\frac{1}{3{-}2000}$ in.

Fig. 737.



Versicular epithelium from thyroid of Pig. Diameter of vesicles, $\frac{1}{2{-}1000}$ in.

Fig. 738.

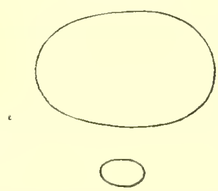


Vesicle from thyroid of Hedgehog, lined by an epithelium consisting of a double row of pellucid delicate vesicles, $\frac{1}{2500}$ in. diam.

from them.* The diameter of these in a human subject averaged $\frac{1}{2000}$ inch; in a bullock, about $\frac{1}{1750}$ inch. They are, in their natural state, perfectly spherical, but often somewhat angular from mutual pressure. Their contents are a very faintly granular or pellucid material, which does not surround a nucleus except in some rare instances, where there may be seen an imperfect trace of one. These vesicles, which I thus name to distinguish them from the nucleated cells occasionally met with, exist in the glandular cavities, sometimes alone, sometimes mingled with the ordinary form of epithelium in varying proportion. I am inclined to believe that they originate in the nuclei, which undergo a kind of expansion, at the same time losing their nucleoli. This opinion needs further confirmatory evidence; it is, however, certain, that they are not developed upon pre-existing nuclei. The layer of epithelium is generally of no great thickness, not occupying more than one eighth or one sixth of the distance from the envelope to the centre of the cavity; in the rabbit, however, it appeared to be more abundant, encroaching considerably on the interior, which, in this instance, was not filled with the characteristic glistening secretion. In a section prepared in the ordinary way, a large quantity of epithelium is broken up, and may be seen strewn over the field. Not unfrequently, however, the nuclei adhere firmly together; and sometimes, as in the pig, I have seen the greater part of the lining of a cavity detached entire.

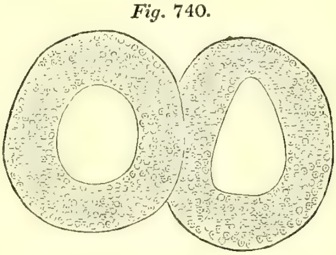
The *contents* of the cavities are for the most part a clear, somewhat refracting, homogenous material, which is manifestly the product of secretion, and fills all the spaces not occupied by the epithelium: this fluid is sometimes contained in small vesicles $\frac{1}{100}$ to $\frac{1}{200}$ inch diam. (*figs.* 739. and 740.) which have a

Fig. 739.



Two vesicles containing a transparent matter and no epithelium. From thyroid of Bullock; the larger $\frac{1}{200}$ in., the smaller $\frac{1}{2000}$ in. diam.

Fig. 740.



Two vesicles from thyroid of Bullock, having a thicker lining of epithelium than usual, and each containing a single vesicle, whose wall, of homogeneous membrane, surrounds the central cavity of the original vesicle.

well marked, structureless envelope, but are destitute of any thing like epithelium. They may be seen occasionally in the interior of the glandular cavities, and also floating free in the field of view, having been perhaps detached from cavities opened by the section. The exact import of this circumstance does not appear; for I cannot regard them as newly formed glandular vesicles, developed within the original ones in an endogenous manner. Were this the case they would occur more frequently, and would exhibit some traces of epithelial lining. Large crystals, sometimes

* I am obliged to use the same word (vesicle) in speaking of the large glandular cavities, and of the epithelial particles which line them; the distinction between them should, however, be carefully borne in mind.

of well marked prismatic, sometimes of octohedral, form, are seen occasionally in the glandular cavities. They are generally single in each, and I have no other guide than their form to lead me to any opinion respecting their chemical constitution. I have seen, in a human thyroid, some large oval or circular corpuscles about $\frac{1}{1000}$ inch diam., consisting of coarse granular matter not surrounded by any distinct envelope, and of an opaque dead white colour. These were perhaps abnormal formations; yet in a tortoise, where the gland was quite healthy, similar corpuscles, and more numerous, were observed. The clear fluid material, contained within the glandular cavities, is generally spoken of as of an albuminous nature. This opinion seems confirmed by two analyses of the gland, made by my friend Mr. Beale, which may be regarded (after allowance is made for the areolar tissue, vessels, envelopes, and epithelium) as expressing pretty correctly the chemical nature of the secretion which forms so large a part of the whole bulk. These analyses I will presently quote, but will first detail a few observations of my own, as to the effects of certain *reagents* on the fluid in question.

Liq. Potassæ, added to a thin section prepared for the microscope, rendered it much more transparent, partially dissolving the epithelium, and leaving a quantity of oily matter diffused throughout it. *Acetic acid* now added to the specimen pretty nearly restored it to its former appearance, but did not bring into view any precipitated protein. *Acetic acid*, alone, dissolves in part the epithelium of the vesicles, and renders the fibrous tissue more transparent. *Liq. Ammoniæ* dissolves the epithelium in great part, but does not alter the transparent contents of the cavities; nor does liq. potassæ or acetic acid. Solution of *iodine* does not materially affect the epithelium of the cavities, but renders it more opaque. Strong *nitric acid* at first renders the epithelium more opaque and granular, but does not manifestly affect the contained secretion. After a time it colours this material bright green or yellowish green, and disengages a great many bubbles of gas. A saturated solution of *bichloride of mercury*, even after long maceration, does not seem materially to affect the secreted contents of the vesicles; it makes their peripheral stratum of epithelium quite opaque; but the interior still appears transparent and glistening.

The chief conclusion deducible from the above results is, that the secreted material of the glandular cavities of the thyroid is not ordinary fluid albumen; as otherwise it would certainly be coagulated by the agents employed. The effect produced by nitric acid is also worthy of notice, though I cannot explain the meaning of it.

Analysis of thyroid gland.

	Human.	*Ox.*
Water - - -	70·6	71·34
Solid matter - -	29·4	28·66
	100	100

Solid matter.

	Human.	*Ox.*
Animal (fibrinous and albuminous) matter, vessels and fat - -	26·384	24·628
Extractive matter -	1·7	
Extractive matter with gelatine - -		2·888
Alkaline salts - -	0·5	0·642
Earthy salts - -	0·816	0·502
	29·400	28·660

The analyses given above testify to the presence of a large quantity of fibrinous and albuminous matters in the gland, and leave no doubt that its secretion is a protein compound; it is, however, unfortunately impossible to procure a sufficient quantity apart from other substances to analyze correctly; and the exact nature of the thyroideal secretion consequently still remains unknown. Thus much, however, seems to be ascertained, or rendered very probable. (1) That the secreted material is of an albuminoid nature. (2) That it is not in the state of ordinary fluid albumen. (3) That gelatine is sometimes an ingredient of the secretion; (it was found in the gland of an ox, but not in that of the human subject, and consequently could not have been derived from the fibrous tissue). (4) That though crystals of triple phosphate and of oxalate of lime occur in the cavities, no urea nor lithic acid, nor in fact any special organic compound, can be detected.*

Vessels. — The vascular supply of the thyroid is very abundant, and completely justifies Cruveilhier's opinion, that more than a mere process of nutrition is carried on in the gland.

The *arteries* which are distributed chiefly to this organ are very constant in their number, and tolerably so I think in their respective dimensions, though in this respect they vary inversely with regard to each other. They ordinarily arise, as has been well remarked by Mr. Simon, just beyond the points where the arteries to the brain are given off from the large trunks,—a circumstance which he conceives to be very significant of the function of the gland which they supply; — the two superior thyroideal arising one on each side from the external carotids, almost immediately after the bifurcation of the common carotids, and the inferior thyroideals from the intrascalenal portion of the subclavian, almost opposite the point where the vertebrals are given off. A fifth thyroideal artery occasionally exists,—that named after Venbauer; taking its origin from the arch of the aorta or the *arter. innominata.* The superior thyroid not unfrequently takes origin a little lower down from the division of the common carotid, or even from its trunk; or it may arise higher up from a common trunk with the lingual. It courses first forward and inward, when it is

* I would not omit to express here my obligations to Mr. Beale for undertaking the analyses, and for the care and skill with which he has performed them.

covered only by the deep fascia and platysma; but it soon turns vertically downwards, and runs beneath the sub-hyoidean muscles to the upper extremity of the gland, where it divides into three branches; one of these runs between the thyroid gland and the trachea, a second skirts the external border of the lateral lobe, while the third, running along the internal border, forms an anastomosis with the corresponding branch of the opposite side.

The inferior thyroid is noticed by Cruveilhier as one of the arterial branches most liable to vary in its origin,—an opinion which, emanating from a less high authority, I should have been inclined to question. It may arise, acccording to him, from the common carotid, the arch of the aorta, or the *arteria innominata*. (The supra-scapular often, less commonly the posterior scapular, and sometimes even the internal mammary, spring from the commencement of the inferior thyroid, which is therefore called the thyroid axis.) Its course is peculiar; it runs at first straight upwards, then comes downward, and again ascends to reach the inferior extremity of the lateral lobe of the gland. It passes in front of the trachea, and behind the great vessels and vagus nerve: the connecting cord of the sympathetic descends behind it to the middle cervical ganglion when it exists, which is then almost constantly found, as it were, seated astride upon the vessel, exactly on the convexity of its first curve. Like the superior thyroid, it has three terminal branches, one running along the inferior border of the gland, another breaking up over the posterior face of the lateral lobe, and a third which penetrates between the gland and the trachea, and anastomoses with the one of the opposite side along the upper border of the isthmus. (Cruveilhier).

The *capillary* plexus, in which the minute branches of these arteries terminate, is disposed in the form of hollow spheres around the glandular cavities, closely applied upon the limitary membrane and forming a continuous network throughout the gland. It is tolerably close-meshed, but not nearly so much so as that of the liver or kidney. The diameter of the capillaries, in a recent injected specimen, varied from $\frac{1}{3\text{-}2000}$ inch, and the interspaces were, I think, two or three times as large.

There are corresponding *venæ comites* to the superior and inferior thyroideal arteries. The superior thyroid or thyro-laryngeal returns its blood either into the internal jugular vein, or into the common trunk of the facial and lingual, before it joins either of the jugulars. The middle thyroideal runs down and turns aside, crossing the common carotid to enter the internal jugular. Besides these there exist constantly another pair of veins, which run down in front of the trachea involved in the deepest layer of cervical fascia, and terminate either by opening both into the *vena transversa*, or the left into this trunk, and the right into the junction of it with the right brachio-cephalic. These veins run down, gradually diverging from each other; so that, from being at their origin no more than one third of an inch apart, they are separated at the lower part of their course by an interval of about an inch, or rather more. In this situation they are often united by a transverse branch, and are said, by Cruveilhier, to form, with the tracheal and laryngeal veins proceeding to unite with them, a considerable plexus, which it is impossible to avoid in the operation of tracheotomy. These veins correspond in some measure with the thyroideal artery of Venbauer, but are much more constant, and are sometimes three or four in number; so that the blood they return is not proportioned to that conveyed by the artery.

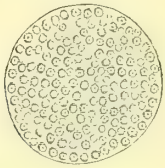
The *lymphatics*, originating probably in a closed network, proceed to enter the deep cervical glands. They may sometimes be seen filled with a concrete albuminous substance, which they have probably taken up from the glandular cavities.

Nerves.— The recurrent laryngeal, shortly before it passes under the margin of the inferior constrictor muscle of the pharynx, gives off some filaments to the thyroid gland; some are also furnished by the external laryngeal; while a plexus, derived from the middle cervical ganglion, proceeds along the inferior thyroid artery, and is distributed to the gland along with its branches, forming communications with the preceding. In thin sections of the thyroid treated with acetic acid, I have seen the nucleated bands of the sympathetic, containing one or two cælio-spinal tubules, running for some distance in the interspaces of the vesicles; they probably terminate by forming a looping plexus; but I have not been able to ascertain anything certain on this head respecting either these or the tubular fibres.

Development. — The thyroid is said by Cruveilhier to be developed by two lateral halves, which are subsequently united by means of the isthmus. This statement seems to be confirmed by the condition of the gland in several of the lower animals, where the lateral lobes continue separate, lying on each side of the trachea; and is also supported by the occasional occurrence of a similar disposition in the human subject.

In my own researches it has not occurred to me to observe this mode of development, perhaps because I have not examined specimens at a sufficiently early period; however, in an embryonic sheep only two inches long, where the thyroid was distinctly visible, it presented the usual appearance—the lateral lobes being connected by a narrow isthmus; the same was the case in a human fœtus of $4\frac{1}{2}$ months; the isthmus, however, being wider, and not appearing to be of at all more recent development than the lateral lobes. In the embryo of the sheep just mentioned, the gland was of an opaque whitish aspect, differing materially from its natural reddish colour; it consisted principally of nuclei, with a small quantity of granular matter. Scarce any trace of a vesicular arrangement existed; but the whole mass was surrounded by an investing membrane very nearly homogeneous in texture. In another embryonic sheep, three inches long, the thyroid was much more of its natural reddish, semi-translucent colour; still there was scarcely any vesicular arrangement, the mass consisting almost entirely of nuclei aggregated together. The thyroid of the human fœtus just mentioned was of the same grayish aspect as that of the smallest of the embryonic sheep. It also consisted chiefly of nuclei, but these were to some extent collected together so as to form solid globular masses (*fig.* 741.), not

Fig. 741.



Incipient vesicle from thyroid of human fœtus, at about mid-period. It is a solid mass of nuclei, not enclosed in a distinct envelope.

yet, however, quite definitely isolated, nor surrounded by homogeneous envelopes. This, however, seems to be the way in which the vesicular cavities are developed; the limitary envelopes being formed around the primitive nuclei, which assume the arrangement of epithelium. The thyroid is of larger relative magnitude during intra-uterine existence and infancy than in after life, — a fact which seems rather opposed to the view which regards this gland as alternating its action with that of the brain.

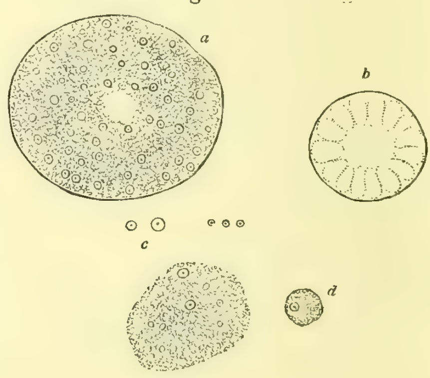
Comparative anatomy of thyroid.—The existence of a thyroid gland in all the *Mammalian* orders seems to be undoubted; and though it is probable that, by a close and extended survey of the various families, some interesting and perhaps instructive peculiarities might be detected, yet I have not the opportunities necessary for undertaking such an inquiry, and can only record one observation where some deviation from the ordinary condition was discovered. This was in a *Rabbit*, in which the organ presented the vesicular arrangement much less manifestly than is usually the case. The epithelium consisted of small imperfect celloid particles, disposed so as to form hollow spheres; but there was scarce any appearance of secretion in the included cavities, which were small, and might at first have escaped observation.

For the following summary of the comparative anatomy of the thyroid in birds and reptiles, I am principally indebted to Mr. Simon's paper in the Philosophical Transactions.

In *Birds*, there are found, in all the various orders, two glands, situated one on each side of the trachea, very near the lower larynx, and frequently attached to the jugular veins. They possess the characteristic structure of the thyroid body, consisting of a dense aggregation of closed vesicles, which contain a kind of epithelium, and are invested by a close capillary network applied over their homogeneous envelope. The position of these glands with respect to the larynx seems to be neither essential nor constant; it is however stated by Mr. Simon, that it "always corresponds to a particular spot of the vascular system, viz., that it lies on the cervical vessels, and receives its supply of blood just opposite to the point at which the vertebral or carotid arteries diverge to their respective destinations."

The following are the details of a microscopic examination which I made of these glands in a Pigeon. They consist of closed vesicles about $\frac{1}{400}$ inch diameter, having their homogeneous envelope lined by a rather thick layer of epithelium, so that the cavity is proportionably contracted, sometimes not being more than $\frac{1}{2000}$ inch diameter The epithelium consists, for the most part, of nuclei and granular matter. Some of the nuclei are very perfect, and show a distinct vesicular structure, with a well marked peripheral nucleolus. Others are more like granules, solid and opaque, and not above half the size. The nuclei are imbedded in granular matter, which for the most part is diffused freely about, but occasionally, though very rarely, constitutes the contents of a cell. In some cavities the epithelium assumes the form of non-nucleated delicate vesicles, of rather large size (*fig.* 742. *b.*). No secretion, capable of being recognised by the eye, exists in the glandular cavities.

Fig. 742.



From the thyroid of a Pigeon.

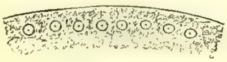
a, b, Two vesicles. The epithelium of *a* consists of nuclei and granular matter; that of *b* of rather large, delicate, pellucid vesicles. The central cavity is small, especially in *a*.
c, The two varieties of nuclei, and —
d, A complete nucleated cell.

Reptiles.—In the order *Chelonia* the organ, which is demonstrated by the microscope to be really the thyroid, is found occupying a definite and uniform position. It lies in the median plane of the body, immediately above the base of the heart, between the two carotid arteries, a ndis overlapped and concealed by the pericardial lobes of the thymus. The structure of the gland in a young Tortoise I found extremely well marked; the vesicles were large, $\frac{1}{84}$ to $\frac{1}{56}$ inch diameter, closely aggregated together, and very variously altered from the spherical form by mutual pressure. There was very little investing areolar tissue. The epithelium consisted of a single row of nuclei imbedded in granular matter, which was more abundant than usually is the case. In some parts this had almost disappeared, and was replaced by delicate vesicles larger than the nuclei which lay closely together in contact with each other. Whichever of these forms the epithelium assumed, it did not encroach much on the cavities of the vesicles, which were large and filled with some transparent non-refracting fluid.

Most of the cavities also contained one to three yellowish coarsely granular globules, $\frac{1}{1000}$ to $\frac{1}{500}$ in. diameter; these existed in various stages of development. A fine large octohedral crystal was also seen in one of the cavities; but there were no prisms of triple phosphate (*fig.* 743.).

Among the various families of the *Saurians* the thyroid is found to occupy different posi-

Fig. 743.



One side of a vesicle from thyroid of Tortoise.

The epithelial stratum consists of a single row of nuclei, imbedded in a more abundant quantity of granular matter than usual.

tions; in some being single and mesial, in others double; in some it lies high in the neck, in others low. Even in the same family its arrangement is not always uniform; thus among the *Lacertidæ* the gland is single, and of considerable breadth in the true lizards while in the Monitor it is double. Among the *Iguanidæ*, likewise, a similar variety prevails. The *Gechotidæ*, *Chamæleonidæ*, and *Scincidæ* present the same general form as the true lizard. In the Chamæleon it is rather higher (nearer the os hyoides) than in the other families, and is overhung by the sacciform dilatation of the larynx.

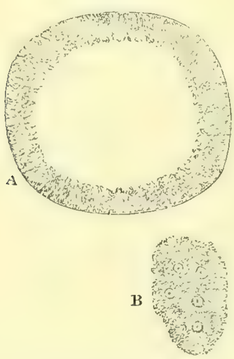
In the *Amphisbania* and *Ophidia* "the gland lies just above the base of the heart, between the right and left carotid arteries. It is a little hidden by the thymus of each side; and in those genera which possess a fat body this large organ lies conspicuously in front of both the thymus and thyroid."

In the *Batrachian* order there has been found, in the common Frog, on each side a small glandular body, which Mr. Simon declares is unquestionably possessed of true thyroid structure. They are situated on the carotid arteries, just beside the cornua of the hyoid bone. Huschkè conceived these bodies to have their origin in the shrinking of the branchiæ, and endeavoured to establish that the thyroid generally had its origin in the transformation of the branchial arches in the early embryo. This hypothesis, however, Mr. Simon well remarks, appears refuted by the existence of the gland in a *perenni-branchiate* animal, the Menobranchus, where it consists of two symmetrical portions connected with the inferior border of the os hyoides, one on each side.

In the class of *Fishes* there seems yet some doubt whether a true thyroid gland really exists. Mr. Simon believes that he has discovered the organ in many fishes, enumerating the Carp (*Cyprinus*), Pike (*Esox*), Cod (*Gadus*), Haddock (*Morrhua*), Whiting (*Merlangus*), Eel (*Anguilla*), Sturgeon (*Accipenser*), Shark (*Squalus*), and Skate (*Raia*); — it seems also to be present in the Anableps, Exocœtus, Callorhynchus, and Lamprey (*Petromyzon*), but the evidence for its existence is less conclusive. It may occupy, he states, either of three positions; (1) as a single organ situated in the median line in connection with the basibranchials, and supplied with blood from the first branchial vein while yet within the gills. (2) "In the Gadidæ the gland is double. One portion lies on each side, not, as in the last case, at the anterior extremity of the first branchial arch, but near its posterior or vertebral end. Here it occupies part of a recess which is bounded by the gill below, and above by the outer extremity of that transverse fold of mucous membrane which limits the extent of the palate. It is merely covered by mucous membrane, which leaves it apparent to the eye without need of any express dissection. Its vascular supply is reflected to it from the ophthalmic artery, which arises before the formation of the systemic aorta from the first branchial vein close to the origin of the proper encephalic artery." (3) "In the carp, anableps, pike, and exocœtus, the gland is placed at the inner extremity of the same duplicature of mucous membrane, and more toward the palate, so as to lie upon the fibres of the pterygoid muscle." Though there is this variety of situation, yet Mr. Simon regards these several organs as constantly agreeing in one point, viz., in deriving their vascular supply from the first branchial vein, and thus being brought into connection with the encephalic nervous centre, by their nutrient streams having origin from a common source. Professor Owen dissents from the view that the pseudobranchiæ are the analogues of the thyroid gland. He states that in osseous fishes they are not diverticular to the cerebral circulation, but only to the ophthalmic, and in most cases are subsidiary, in this respect, to the choroid vaso-ganglion. The sublingual gland of Retzius is the organ which Professor Owen considers as most nearly representing the thyroid, though he suggests a doubt as to whether, by reason of its relations to the heart and great vessels, it may not more properly be regarded as the analogue of the thymus.

It is with some hesitation that I proceed to mention the results of my own examination of some specimens from the three classes pointed out by Mr. Simon, in which he seems to regard the presence of a thyroid as undoubtedly ascertained. I have, however, carefully examined the structure with the microscope in every instance, and I believe I may refer to the observations, so far as they go, as free from any material error. In the *Skate* I have found the organ described by Retzius as a salivary gland, and by Mr. Simon as a thyroid, occupying the situation well described by the latter, and lying exactly upon the terminal division of the branchial aorta. It was of a faint reddish gray tint, and presented to the unaided eye the appearance of a conglomerate gland. No excretory duct, however, was observed proceeding from it. In structure it consisted of numerous vesicles aggregated together. The form of these was mostly circular; some were elongated, and many variously altered by mutual pressure. Their diameter was about $\frac{1}{112}$ to $\frac{1}{67}$ inch (*fig.* 744. A). The limiting envelope of the vesicles presented a

Fig. 744.



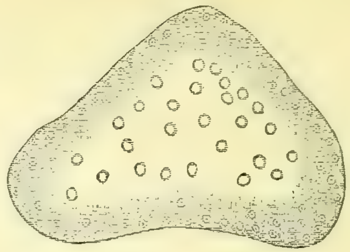
From thyroid of Skate.

A. Vesicle, $\frac{1}{17}$ in. in diameter.

B. Several of the nuclei imbedded in diffused mottled substance.

good example of homogeneous membrane. It was lined internally by a pretty thick stratum of epithelial substance, which in some instances was so abundant as almost to fill up the cavity. The epithelium consisted of nuclei and a very large quantity of rather coarse granular material, which quite obscured the nuclei themselves (*fig.* 744. B.) There were also a few granular cells, and, in the interior of many of the vesicles, imperfect prismatic or octohedral crystals could be discerned. I could not discover, among the glandular structure, any tubes resembling excretory ducts; so that I am much inclined to believe it has no relation to the salivary organs, but belongs to the class of ductless glands. A gland, however, it assuredly is, and not a mere vaso-ganglion. Besides this body I discovered at some distance behind it, just at the junction of the branchial arches anteriorly, a small light reddish mass, which was covered in by a thin fascia, and by the mucous membrane, and could not be seen till the latter was dissected off. Its structure was almost exactly similar to that of the organ just described, consisting of vesicles about $\frac{1}{150}$ to $\frac{1}{100}$ inch diameter (*fig.* 745.), with a thick interior stratum of epithelium resting on a beautiful homogeneous limitary membrane. The pseu-

Fig. 745.



A vesicle from sublingual gland of Skate, diam. $\frac{1}{99}$ in.

It contains abundance of nuclei and granular matter, with delicate vesicles.

dobranchia, situated on the anterior wall of the spiracular canal, is manifestly of entirely different structure to the organs described. It consists of small plicæ of mucous membrane, covered by a kind of pavement epithelium. In a Dog-fish (*Spinax*) the pseudobranchia was very small, but distinct. I could discover no trace of the sublingual gland, or of the small one behind it which I found in the skate.

In the *cod* and *whiting* the pseudobranchia is situated, as Mr. Simon has described it, near the upper extremity of the first branchial arch on each side. It lies in a recess which is bounded by the gill below, and above by the outer extremity of that transverse fold of mucous membrane which limits the extent of the palate. Its structure is peculiar; Mr. Simon regards it as a thyroid; but from this opinion I feel obliged to differ. The following description is taken from examination of the organ in the Cod, but applies equally to that in the Whiting. It is a body of light red colour, semi-transparent aspect, flattened so as to present two faces, about one line and a half in thickness, and having two borders, one convex and slightly notched, the other somewhat concave. The surface is slightly uneven or nodulated. It is enclosed in a capsule, through which some large vessels are seen ramifying. Its general aspect is that of "glandular flesh," and certainly not of a mere congeries of vessels. In structure it appears to consist of parallel folds of homogeneous membrane, beneath which is spread a vascular plexus, and which are covered by an unusually developed epithelium. This epithelium appears under the form of granular cells of an oval, circular, or irregular form, not distinctly nucleated, and having a diameter of $\frac{1}{2\text{-}1000}$ inch. These do not appear to constitute a mere investment, but to form a layer of some thickness, filling up the intervals between the adjacent processes or folds of homogeneous membrane. These organs, manifestly constructed after the type of gills, evince thus a tendency to assume a glandular structure; yet I can see no sufficient reason for supposing them to represent the thyroid, from which they differ so entirely in structural characters. In the whiting I could detect no trace of a sublingual gland, nor of the small posterior one; but in the Eel, where the pseudobranchia was absent, I found, by the aid of the microscope, between the first and second basibranchials, a small mass, which consisted in great part of fat, but contained also some large vesicles closely resembling those of a real thyroid. Their diameter varied from $\frac{1}{100}$ to $\frac{1}{66}$ inch. They had an homogeneous envelope lined by an epithelium, consisting of small non-nucleated pellucid corpuscles, and surrounding a cavity filled by a transparent somewhat refracting fluid.

In a *Pleuronectid* I found the pseudobranchia quite free, uncovered by mucous membrane, and projecting a series of small distinct leaflets into the branchial cavity. It differs essentially from that of the cod or whiting, and showed no tendency to assume a solid glandular form, but was manifestly a real though minute gill.

In a *Carp* I found the pseudobranchia with some difficulty. It was situated very deeply between the anterior part of the upper extremity of the first branchial arch, and the posterior border of the pterygoid muscle. Its structure was entirely that of a gill, consisting of parallel folds of a membrane, arranged transversely to a median axis, and overlaying a vascular plexus. These folds were covered with a kind of scaly epithelium, which was often detached in large pieces, and mingled with some circular cells, closely resembling mucous globules. I could find no trace of the sublingual nor of other adjacent gland.

From the few facts now detailed I think it may be concluded, (1) That there is no evidence from their structural characters to prove that the pseudobranchiæ are the representative of the thyroid. (2) That in some instances organs which seem to be of a totally different kind are found, which resemble very closely the structure of the thyroid when it unquestionably exists. Mr. Simon lays stress upon the circumstance, that the pseudobranchiæ and the sublingual gland receive their vascular supply from the same source, viz. the 1st branchial vein; this, however, is not constantly the case, the pseudobranchiæ in osseous fishes, according to Professor Owen, serving only as diverticula to the ophthalmic, and not to the cerebral circulation; so that on this ground they cannot be supposed to have similar functions. For a philosophical discussion, however, of the analogy and homology of the pseudobranchia to the thyroid, I would refer to Professor Owen's Lectures, vol. ii. p. 270. *note*.

Morphology. — The preceding details are abundantly sufficient to prove the glandular nature of the thyroid. This truth, which elder anatomists saw clearly, though rather afar off, we, by more intimate and minute scrutiny, are enabled to confirm and establish in every particular. Let us take in order the several parts of the secretory apparatus of the thyroid as we have described them, and see whether they do not exactly correspond to homologous parts in any undoubted gland. The receptacular cavities, enclosed by envelopes of homogeneous membrane, manifestly represent the tubes of the kidney or testis, or the terminal vesicles of the salivary gland. The limitary tissue is identical in appearance in each; but disposed in the one so as to form shut sacs; in the others to ensure a pervious canal or outlet, for the secretion. In the true glands the limitary tissue or basement membrane supports, on its interior, a layer of epithelium, essentially consisting of nuclei and granular matter. The same tissue in the thyroid is lined internally by a similar layer, which differs only in the smaller quantity of granular matter interposed among the nuclei, and in both cases the formation of perfect cells (*i.e.* with envelopes) is uncommon. The exterior of the limitary tissue is in contact, in all the true glands, with a capillary plexus, from which the materials for the nutrition and growth of the epithelium are furnished. The same disposition exists in the thyroid. A certain amount of fibrous tissue, or some modification of it, penetrates more or less extensively among the elementary parts of the true glands, and serves to pack and unite their component parts together; this also we have had occasion to describe in the thyroid. With respect to a supply of lymphatic vessels and nerves, it is sufficient to state, that as far as ordinary dissection can go, the thyroid is similarly circumstanced with the other glands; and there is no reason to doubt that the actual arrangement of these parts in all is the same. The parallel, thus exactly sustained in every particular, warrants us in regarding the thyroid as the παράδειγμα of the class of ductless glands, and it may be not without advantage, if we take occasion to note, in the other organs belonging to the same class, how gradually the strongly marked characters are laid aside, till the glandiform organ passes into a modification of vascular structure. In the supra-renal capsules the limitary membrane, though described by an eminent anatomist as usually forming tubes of various length, enclosing celloid epithelial particles, is, according to my observation (which is however but limited), very faint, or entirely absent. I have never been able to discover it in the human adult or fœtal subject; and in the sheep the cortical structure has seemed to consist simply of rows of celloid nucleated particles, without any enclosing membrane. Conceding, however, that in these organs the limitary tissue does exist, there can be no doubt that it is much more feebly developed than in the thyroid, while, as a set off, the epithelial particles are more perfectly formed. In the case of the thymus the limitary tissue is well marked, and resembles very much, in its arrangement, that of the conglomerate salivary gland; but the epithelium is remarkably modified. The nuclei exist, but almost alone. No granular matter of any peculiar properties is formed around them, preparative to, and evidencing the existence of, secretory action. In the spleen both these alterations coincide. The epithelium is reduced to mere nuclei aggregated in masses round prodigiously developed venous radicles, and the limitary tissue is discoverable nowhere, not even surrounding those curious spherical masses of nuclei the white corpuscles of Malpighi. The only circumstance I know of, which seems to indicate that even in the spleen a kind of secretory action does occasionally take place, is, that there frequently occur, in the parenchyma, some peculiar yellow corpuscles, which are most abundant in fishes, and of which I gave a detailed account some years ago. The very presence, however, of these (for they are by no means constant), as well as their condition, argue strongly that secretion is not the appointed function of the splenic parenchyma. From this, the last and lowest of the ductless glands, we descend to erectile tissue, in which the venous portion of the sanguiferous system is even more highly developed than in the spleen, and where the intervening parenchyma is still further reduced in quantity; yet, from the phenomenon of afflux of blood to the part, it must be regarded, I think, as exerting an attractive force, as is unquestionably the case in the spleen.*

Returning from this digression to the consideration of the thyroid, we may lay it down as fully established, that it is a gland whose secretion is formed, and collects, in closed cavities. Now from this fact we are able easily to deduce another, viz., that the secretion when formed is capable of being absorbed from the receptacular cavities; for otherwise these would go on enlarging and distending themselves indefinitely, as in fact they do under certain morbid conditions. But, though there may be various causes concerned in the production of bronchocele, yet I think it must be regarded as proved, by Mr. M'Clellan's inquiries, that certain waters are adequate of themselves to produce this disease;—it would appear that when they are drunk, some ingredient or principle is supplied to the blood, which, being in excess, is straightway eliminated by the epithelium of the glandular cavities of the thyroid, and thus collects in, and distends them. If a patient in whom this has occurred be removed from using this unwholesome water, and if the natural absorbing power be aided by the influence of iodine, then, the supply of the substance for which the thyroid has a special attraction being cut off, the excess collected in the receptacular cavities returns speedily to the circulating current, which now, being in a minus condition as to this principle, readily resumes it. In such cases there seems, in fact, to take place a very analogous process to that which occurs in ordinary fattening and emaciation; if an excess of oily matter exist in the blood, old fat vesicles enlarge, and new ones are formed; if the reverse is the case, the oil in the fat cells is readily absorbed into the blood circulating in the capillary loops around them.

The condition in which the epithelium of the thyroideal cavities is usually found is worth observing, and seems susceptible of a probable interpretation. It may be stated as a pretty well established fact, that the nucleus of a cell is the essential part, that in it resides that influence, or is developed that force, which produces all the phenomena of growth and assimilation; that, so long as the nucleus persists, the energy of the cell, if one has been formed, continues to be manifested; but, if it has disappeared, the *active* life of the cell is at an end. It is also certain that the completion of a cell, *i.e.* its being surrounded by an envelope, is by no means an essential circumstance; that all the purposes of cell life may be effected by the mere aggregation of granular matter around a nucleus; that, in fact, the cell wall or envelope is of no importance, or but very little, in the metabolic changes which are produced, and that its presence, when it exists, seems merely to denote a certain permanence of duration in the particle. Many examples of the correctness of these statements, will occur to every one who is in the habit of examining the glandular organs in man or the lower animals. I believe we may also advance a step beyond these doctrines, and regard it as very probable that, when we find an epithelial structure consisting principally of *bare* nuclei, with but a scanty interposed quantity of granular matter, the secreting action there effected is of a rapid and simple kind; the destined product being quickly formed and thrown off, and not slowly evolved within the chamber of a cell. The following instances may be referred to, as illustrating the extreme varieties of secretory action in reference to this particular. The cells in which the spermatozoa are formed must be of considerable permanence, the development of the filaments taking place gradually, and in one instance, as Mr. Goodsir has shown, only being completed in the spermatheca of the female. The biliary cells of various annelida are at first filled with pale granular contents; but *gradually* these are replaced by the characteristic molecules with which the cell becomes at last distended, and thus remains, often for a long time. The cells of the kidney of the common snail, which are very perfectly formed, enclose, within a well marked envelope, an opaque white mass of uric acid, which, after a long time, may increase to such a degree as completely to fill the cell. These cells are very permanent.*

In contrast to these instances, wherein complex and elaborate products are formed in *complete* cells by a secretory action of a slow and deliberate character, we may refer to (1)

* The well marked variation in size of the spleen at different times proves, I think beyond doubt, that it exerts an actively attracting force on the blood which traverses it; else what possible reason can be given for its containing much more blood at one time than at another? No contractile tissue exists here which can be supposed to obstruct the returning current by the splenic vein.

* I preserved some snails in a box for about a year—they remained in a perfectly torpid state, and took no food. The renal cells at the end of that time were almost all fully distended with uric acid, while usually they are not more than half full.

the absorbent glands, which doubtless produce some change in the fluid which traverses them; this, however, must necessarily be a rapid process, and, accordingly, scarce any cells are formed; the mass of the glandular parenchyma consisting of very perfect nuclei; (2), the terminal hepatic ducts, whose walls, as I have shown, consist almost entirely of nuclei set close together, and which, by means of these effective agents, eliminate the actual biliary secretion from the varying, partly biliary, partly oily, fluid formed by the hepatic cells on their *exterior;* this process of elimination is, I believe, continually going on, and is not so much of a metabolic as of an absorbing nature; the essential change being probably effected by the hepatic cells of the lobules; (3) the nucleated tissue forming the principal part of the villi, which scarce ever developes cells,* but is constantly attracting the chylous fluid through the basement membrane from the cavity of the gut, and permitting it to pass off by the efferent lacteals (here scarce any chemical change appears to take place); (4) the cineritious matter of the cerebral hemispheres, which, amid the rapid alternations of sensation, thought, and volition, must be undergoing incessant change, consists, in by far the greater part, of nuclei and granular matter, the fully formed vesicles being few and far between.

Applying, now, these views to the case of the thyroid, there seems reason to believe that the ordinary condition of its epithelium is such as to adapt it for rapid and transitory action; so that a large amount of secretion may be quickly thrown into its cavities on any sudden occasion; which again would easily transude through the *thin* epithelial layer and homogeneous tunic, when the time of action had passed by.

It may also be remarked, as consonant with the views above stated, that as respects its chemical nature the secretion of the thyroideal cavities is of a simple kind, not apparently requiring much elaboration. It seems, in fact, to be a mere modification of albuminous matter containing, it may be, some gelatine, but strongly contrasting with the highly wrought products of the renal and hepatic laboratories. This implies that the change effected by the thyroideal epithelium on the liquor sanguinis supplied to it is by no means considerable.

Use.—Cruveilhier, writing about fifteen years ago, briefly says, "the use of the secretion of the thyroid is unknown;" nor can the anatomist of the present day give a much more satisfactory account. So enveloped in mystery the use of the gland seems to have been always regarded, that inquirers have been more willing simply to confess their ignorance than is usually the case, and fewer speculations and hypotheses have been broached respecting this than regarding other points which promised at first sight to be of easier solution. It is scarcely worth while to mention the opinion, which supposes the thyroid to have any essential connexion with the larynx, either as pouring into it, through supposed ducts, a fluid fitted to lubricate the lining membrane, or, as Sir A. Carlisle supposed, forming a protection to the delicate organs of the voice, against the variations in temperature of the external air. There seems no doubt that the relative position of the thyroid to the larynx is quite unimportant, so far as the function of the organ is concerned. This is borne out by the variations of its site which occur in birds, and by the results of morbid action; since prodigious goitre does not induce disease of the larynx, except in a mechanical way, *i. e.* by injurious pressure.

Passing over more crude conceptions, we come to consider a theory which has been propounded by Mr. Simon, and which has certainly every claim to our careful attention, both from the character of its author, and as it is the only one yet promulgated which can be said to be even probable. He considers that the thyroid acts as a diverticulum to the cerebral circulation; exercising, at the same time, its secretory function in an alternating manner with the encephalic nervous mass. His words are, "What *diversion* is to the *stream* of blood viewed quantitatively, alternative secretion would be to the composition of blood viewed qualitatively; and I should conceive that the use of the thyroid gland, in its highest development, may depend on the joint exercise of these two analogous functions. I should suspect not only that the thyroid receives, under certain circumstances, a large share of the blood which would otherwise have supplied the brain, but also that the secretion of the former organ bears some essential relation (which chemistry may hereafter elucidate) to the specific nutrition of the latter; that the gland,—whether or not it appropriates its elements in the same proximate combination as the brain does,—may, at all events, affect, in a precisely similar degree, the chemical constitution of the blood traversing it; so that the respective contents of the thyroid and cerebral veins would present exactly similar alterations from the characters of aortic blood. Finally, I should suppose that these actions occur only, or chiefly, during the quiescence of the brain, and that when this organ resumes its activity the thyroid may probably render up again from its vesicles to the blood, in a still applicable form, those materials which it had previously diverted from their destination."

This theory mainly rests on the circumstance that the thyroideal arteries arise in close proximity to the cerebral, and this is I think sufficiently constantly the case to form a strong argument in its favour. It must be remembered, however, that variations in the place of origin of the arteries both of the brain and thyroid, do occur without, as far as we know, any interference with the full discharge of the functions of the gland; and it may also be considered probable that the purpose of a diverticular stream would have been better

* I venture herein to differ from Professor Goodsir, not without repeated and careful observations.

attained, if the origin of the vessels had been *below* instead of *above* the point of giving off of the arteries to the brain. Besides, however, this argument, two others may be mentioned which at least favour the same view. One is, that no special characteristic principle appears to exist in the secretion of the thyroid, but that it is a mere modification of albuminous matter,—this seeming to imply that no special use is served by the secretion of the gland, that it is not elaborated for the sake of producing any peculiar effect on some other part, but that it is simply *secerned* from the circulating current for a time, to return and mingle with it again in a condition but little altered from its primitive one of blood-plasma. The other argument is drawn from the condition of the epithelium, which, as we have before remarked, seems adapted for rapid and transitory action, so that it might quickly secrete a large amount of material on any diminution of the nutrient processes in the brain. These arguments may be allowed to possess some weight. Before, however, this theory can be regarded as at all established, a more sure and discriminating chemistry must prove some relation of composition to exist between the secretion of the thyroid and the grey nervous matter. Till this is done we can but deal with the question afar off, without bringing it to an exact issue.

Morbid Anatomy.—The following morbid changes have been observed to occur in the thyroid; (1) It may be affected with common inflammation. (2) It may be variously altered by unhealthy or perverted action of its own glandular structure. (3) It may be the seat of adventitious formations. (4) Its vessels may become remarkably enlarged, as in the so called aneurism by anastomosis.

Inflammation. — Professor Hasse gives the following description of inflammation occurring in the thyroid. " It is rare, but may attack the organ either when healthy, or when enlarged by previous disease. Its course is more frequently chronic than acute. Within a very brief interval the gland often swells considerably, becomes very bloodshot, tense, and painful, its texture softened and friable, assuming at first a brown red, and ultimately a dingy gray colour. The morbid anatomy of this grade of inflammation is but imperfectly known; that of the suppurative stage has been more frequently observed, and more fully described. Either separate abscesses form, or else the entire gland is converted into pus. Under favourable circumstances the abscess opens externally through the skin. There are, however, examples of its obtaining vent through the œsophagus, and determining a protracted fistula of the gullet,* or of its discharging itself into the trachea, and producing death by suffocation.† After evacuation of the pus, together with numerous shreds of dead cellular tissue, the tumour collapses; the gland on the side affected shrivels into a hard, cellulo-filamentous knot, which adheres firmly to the skin and to the surrounding parts. Sometimes the shrivelling of the one gradually brings on wasting of the other lobe."

* Unger, Beitrage zur Klinik der Chirurg. vol. i.
† Meckel.

Alterations of Structure. — Under the second head may be included *hypertrophy* of the thyroid, or some enlargement without appreciable change of texture. " This variety," Prof. Hasse states, " is frequent, and for the most part inconsiderable." It probably depends merely on distension of the glandular cavities by their accumulated secretion. This change is almost wholly " confined to youth, and is frequent about the age of puberty in both sexes,— more so, however, in the female." " Alternatives of increase and decrease are especially apparent in this kind of bronchocele, enlargement being most conspicuous at the approach of the menstrual period." This form, though it may be called hypertrophy, is not quite strictly so designated, as there is no formation of new glandular tissue, but only distension of the original cavities, by an increased quantity of secretion.

" *Melicerous degeneration* of the thyroid is one of the most frequent forms. It occurs at all ages, and is uniformly attended with intumescence. It may involve the organ in whole or in part. In the former case the component granules (or vesicles) are found unusually and unequally enlarged, and transformed into separate cells filled with a tenacious, viscous, jelly-like substance, of the colour of honey. The entire part is hard, nearly bloodless, and but loosely coherent with the surrounding parts. Where, as frequently happens, only certain portions are disorganized, these form spherical tumours varying in size, and imbedded clearly in the healthy structure. They present a brownish or yellow colour, and the consistency of jelly or of melted glue. Sometimes they appear as an opaque, reddish, soft, or even lardaceous, swelling. In general but few blood vessels are visible in this goitre, although it may now and then be associated with exuberant vascular growth."

The foregoing description is quoted from the translation by the Sydenham Society of Professor Hasse's work. He does not, however, seem to notice sufficiently, under this head, the variety of matters which are found in the enlarged glandular cavities. Cretaceous matter, either in a pulverulent state, or forming hard ossiform masses, I believe often occurs, and in Prep. 1498, of the Pathological collection in the Museum of the College of Surgeons, there is seen a quantity of solid white substance, either opaque and soft, or transparent, firm and chondroid, which occupies the larger cavities, the majority being filled with a transparent jelly-like material; some also with cretaceous matter. One interesting instance, probably belonging to this class, is quoted in the Cyclop. of Pract. Medicine from De Häen:—" In cadavere horrendam mole thyroideam nactus, publicè dissecui. Mecum auditores mirabantur, nullum fere genus tumorum dari, quin in hâc solâ thyroideâ inveniretur. Hic enim steatoma, ibi atheroma, alio in loco purulentus tumor, in alio hydatrius, in alio erat coagulatus sanguis, fluidus fere in alio, imo hinc glutine loculus plenus erat, alibi calce cum sebo mista."

I may mention here the results of microscopic examination of a specimen of this form of enlarged thyroid, for the opportunity of making which I am indebted to the kindness of the medical officers of St. George's Hospital. The gland was greatly enlarged; its surface somewhat nodulated. A section displayed a number of cavities visible to the naked eye, some of which were circular, others elongated, and as it were compressed. Many of them were about the size of a large pin's head; some however, much more capacious. The majority were filled with a slightly opaque, firm, gelatinous material; but some (the larger) with cretaceous or ossiform matter, and some also with a reddish material. The intervening structure in several places appeared tolerably natural; but even in this, on close inspection, enlarged vesicles were perceptible. The areolar tissue separating the lobes of the gland was hypertrophied, and formed whitish septal bands. Under the microscope it was seen that the vesicles were generally enlarged. They were found of all sizes, from those that were distinctly visible to the naked eye, or still larger, down to the natural size. Their walls were somewhat but not uniformly or very greatly thickened. The homogeneous envelopes presented, generally, somewhat of a fibrous appearance. The greater number of the cavities were distended with a transparent, feebly refracting, structureless, material, in which were numerous small irregularly shaped particles of higher refracting power. This material resembled, almost exactly, the normal secretion in appearance, and, like it, was free in the cavity of the vesicles. In these vesicles there was very little trace of epithelium, only some small, and few, non-nucleated corpuscles; but in other vesicles the epithelium was so abundant, that it completely occupied the cavity. It was in no respect different, except as to quantity, from its healthy condition, consisting of mere nuclei and interposed granular matter in no great abundance. In some of the vesicles there were large and beautiful crystals of more or less perfect octohedral form. These were either oxalate of lime or triple phosphate. One prodigiously enlarged vesicle contained a mass of calcareous matter, very firm and dense throughout, but most in its central and peripheral parts. In the latter situation there were numerous masses of ossiform substance, of yellowish semi-transparent aspect. On crushing these, no bone lacunæ could be discerned in the fragments. They dissolved freely with strong effervescence in nitric acid, leaving an homogeneo-fibrous basis substance, which often exhibited a greenish yellow tint. The material, thus proved to be of cretaceous nature, contained, mingled with it, numerous tablets of cholesterine. One small reddish mass, occupying the cavity of a vesicle, was found to consist almost wholly of blood globules and their detritus, and thus seemed to be the result of hæmorrhage. Another opaque whitish mass did not effervesce with nitric acid, and was therefore not cretaceous; it consisted of epithelial nuclei mingled with peculiar, and rather abundant, granular matter. In the above account it is worth noticing that no *cells* were found; the epithelium retained its natural appearance; also the matter distending the greater number of the cavities resembled exactly, so far as the eye could judge, the natural secretion; and lastly, that in some instances there was an accumulation of unaltered epithelium and not of the secretion. This last fact is of some importance with respect to the exact nature of the function discharged by the epithelium.

Owing to the kindness of my friend, Mr. H. Gray, I have recently had the opportunity of examining a remarkable specimen of *Bronchocele*. The gland was greatly enlarged,—to five or six times its natural magnitude,—and altered in form, one lateral lobe being raised up higher than the other, and the surface being somewhat uneven and nodulated. On a section being made, the exposed surface presented a reddish glossy aspect, somewhat resembling that of certain forms of malignant disease which are undergoing softening: there was no appearance of distended cavities; in fact, the structure to the eye exhibited less of the cellular arrangement than is usual. Microscopic examination confirmed the impression derived from simple inspection. — But little of the natural secreting structure remained, the vesicles being destroyed, and their secretion, though still present in some quantity, being certainly diminished. Some traces of the epithelium of the cavities were perceptible; but there was no special cell growth indicative of any adventitious formation; a few large cells or globules only, varying in size from $\frac{1}{650}$ to $\frac{1}{1500}$ in. diameter, existed in some of the remaining cavities: these evidently consisted of aggregations of oily molecules and drops not manifestly enclosed by any envelope. The blood-vessels were prodigiously and universally enlarged; some of those which were capillaries in structure were from two to three times their normal diameter, and irregularly dilated and varicose; they were every where clustered over with minute oil drops; which formed so thick a coating to many of them, that they appeared as white cylinders by direct light. Some parts of the gland presented to the naked eye a whiter aspect than others; and in them it was seen that the deposit of oily matter along the vessels, and the destruction of the glandular tissue, had proceeded to the greatest extent. In some places there were masses of ossiform deposit.

The morbid alteration now described approaches most nearly, I think, to the vascular and aneurismatic bronchocele; but the extensive destruction of the glandular tissue, and the copious deposit of oily matter, show that there must have been some grave derangement of the nutrition of the gland. The case occurred in a female (æt. 75.), who died with cirrhosis of the liver and ascites; the kidneys contained numerous small cysts, and there were two fibrinous blocks in the spleen.

Adventitious formations. — Cystic formation within the thyroid is next described by Professor Hasse; and regarding it as depending on the development of new cysts within the gland, and not on the perverted or excessive action of its own natural vesicular cavities, it will fall under our third head. I am, however, rather in doubt whether most cases of cystic formation in the thyroid do not belong to the second category, and are not dependent on the development of any adventitious structure. Prof. Hasse says, "cystic formation within the thyroid gland is one of the most frequent causes of goitre. It occurs both by itself, and in conjunction with other kinds of degeneration, and constitutes the largest and most unsightly of all tumours. Cysts of every variety and size, either solitary or in congeries, are encountered in every part of the thyroid gland; an entire lobe, nay, the greater portion of the whole organ, being sometimes engaged in cystic development. The surrounding texture is seldom healthy, being generally compressed, flabby, and bloodless. The cysts are, for the most part, isolated. Occasionally, however, they abut one upon another, so as to form a single multilocular capsule. Here, as elsewhere, they are composed of two membranes; namely, an external filamentous, and an inner serous, one. The external membrane is either smooth, or sends forth bands which attach it closely to the rest of the texture; in many instances it partially, if not wholly, ossifies. The sac contains a limpid fluid, or a number of secondary hydatids *, or, again, a jelly-like substance, but more commonly a yellowish or whitish crystalline pulp, consisting almost wholly of cholesterine crystals with phosphate and carbonate of lime. In some instances the cyst accidentally inflames and becomes atrophied; in others it gradually fills with earthy matter, and is transformed into a hard calcareous nodule. Cysts occur in the thyroid gland, in both sexes, and nearly at all ages; more frequently, however, in females after the prime of life." A remarkable case of cystic formation in the thyroid is mentioned by Andral. He states that the whole organ was converted into a cyst with bony walls filled with a honey-like fluid. He seems to recognise both the cystic and melicerous degeneration as further stages of the perverted or excessive action which occurs in simple hypertrophy, and justly refers to the case of the ovary as exactly analogous, the cysts of which, filled with various products, originate, in all probability, in Graafian vesicles, which undergo an abnormal development.

Prof. Hasse has never met with *tubercles* occurring in the thyroid. Prof. Louis makes no mention of such an occurrence, nor does M. Papavoine in a table which he gives of the seat of tubercle in various degrees, drawn up from the examination of the bodies of fifty children.

Sauten has observed that persons affected with extensive bronchocele seldom or never become subjects of phthisis.

Carcinomatous growths rarely affect the thyroid. Eight cases in 8289 of deaths occurring from cancer in Paris, are ascribed to this part. * The disease is sometimes primary, sometimes secondary, or the result of invasion from some neighbouring affected part.

Encephaloid or *scirrhus* in several of their varieties have been known to occur in the organ, but no example of *colloid* in it has yet been detected: of course cysts filled with melicerous contents must not be confounded with the loculi of real colloid, to which they bear some resemblance. Primary cancer in the thyroid usually exhibits the characters of scirrhus, secondary those of encephaloid: in the first case the disease is usually infiltrated, in the second of the tuberous form. Encephaloid here, as elsewhere, often grows rapidly, and attains a large size. It seems to obliterate entirely the natural appearance of the gland. It is often of the *hæmatoid* variety, in which there is sometimes softening in the centre of the mass, causing rupture of vessels and extravasation of blood. Occasionally black pigment is accumulated within its texture in varying amount, "Medullary cancer of this gland must not be confounded with that of the lymphatic glands of the neck, which often simulates goitre."

Enlargement of the Vessels. — The last kind of morbid degeneration, which the thyroid has been observed to undergo, is that to which the term vascular or aneurismatic bronchocele has been applied. It is described as follows by Professor Hasse,—"All the blood vessels are much amplified, the veins in particular forming very dense, capacious, often knotted, plexuses, and the whole texture consisting apparently of a dense coil of vessels. The substance of the gland has almost entirely lost its granular character; it is flabby and dark red. After death the tumour collapses considerably, and can only be restored to its original size by artificial injection. The walls of the arteries and veins are attenuated, the dilated membranes of the vessels contain considerable clots, and capacious cavities are found filled with black coagulated blood. Vascular bronchocele affects the entire gland; principally, however, one or other lobe. It occurs most frequently in females after the prime of life, and is, like simple hypertrophy, marked by periodical augmentation and decrease. This general dilatation of blood-vessels must not be confounded with the exuberant vascular (malignant) growth termed fungus hæmatodes, to which the thyroid gland is also subject." In the foregoing description we have clearly set forth the condition of an organ, the walls of whose vessels have, from loss of their natural tonicity, yielded to the

* Lieutaud mentions a case where the trachea was perforated by one of these acephalo-cysts.

* Walshe on cancer.

impetus of the current of blood, and being thus enlarged and distended, have pressed upon the essential structure of the gland, and caused it to become atrophied.

It may not be amiss to observe, after this review, that the disease of the thyroid, which is of by far the most frequent occurrence, viz. enlargement of its magnitude from excessive or perverted secretory action, is just of the kind we should, from our knowledge of its actual structure, expect would be most liable to occur. For when once the nicely arranged balance of secretion and absorption, with its moderate alternating oscillations in either direction, is permanently deranged, the closed cavities of the glandular vesicles afford no exit to the accumulating matters. Thus does minute anatomy explain, and thus is it confirmed by, the changes wrought by disease.

History of Investigations. — The following is not presented as a complete history of the thyroid, but as a sketch which it is hoped contains the principal facts relative to the advance of our knowledge respecting it.

In examining the works of Aristotle, I find he makes no mention of the thyroid in two places, where he describes the organs situated in the neck, and speaks especially of the trachea. Galen does not give any very distinct account of the thyroid, so far as I have been able to discover; but certainly seems to allude to it in a passage in his book "On the Use of the Parts of the Human Body," where he speaks of the glands of the larynx, "which are always found more loose and spongy than others, and which, by the common consent of anatomists have been created for the purpose of moistening and bathing all the parts of the larynx and the passage of the throat." The following passage, quoted also in a note by Morgagni *, seems to prove that he was aware of the main peculiarity of the thyroid. "Now the neck has two glands, in which a moisture is generated. But from the two glands which are in the neck there come forth no vessels by which the moisture may flow out, as those do from the glands of the tongue." Vesalius, who wrote about A.D. 1542, distinctly recognises the existence of the thyroid in the following passage from his work, "De corporis humani fabricâ." † "And this dissection also shows two glands, adhering one on each side, to the root of the larynx, which are of large size, and very fungous, and nearly of the colour of flesh, but darker, and covered over with very conspicuous vessels." In the second book he describes their appearance in oxen, in whom they resemble muscular tissue, he says, very much, while in man their aspect is more truly glandular. Jacobus Sylvius, who wrote a little later than Vesalius, enumerates, in his list of glands, "duæ item ad laryngis radicem asperæque arteriæ initium utrinque una quæ interdum ob magnitudinem in unam abire videntur." Wharton, in his Adenographia, published about 1656, gives a very full and good description of the thyroid; he notices its situation, figure, magnitude, texture (substantiam), and consistence (soliditatem); and remarks "that it is much more full of blood than any other gland, also more viscid and solid, and more resembling muscular flesh. This is the only difference, that it is not of a fibrous structure, but rather of a glutinous nature." He assigns four uses to the gland, which it may be worth while to quote, as affording an example of the speculations then in vogue, the last perhaps being not the least real and important of those he mentions! "(1) The first and principal use of these glands appears to be to take up certain superfluous moistures from the recurrent nerve, and to bring them back again into the vascular system by their own lymph channels. (2) To cherish the cartilages to which it is fixed, which are rather of a chilly nature, by its own heat; for it is copiously supplied with arteries, and abounds with blood, from whence it may conveniently impart heat to the neighbouring parts. (3) To conduce by its exhalations to the lubrication of the larynx, and so to render the voice smoother, more melodious, and sweeter. (4) To contribute much to the rounded contour and beauty of the neck; for they fill up the empty spaces about the larynx, and make its protuberant parts almost to subside and become smooth, especially in the female sex, to whom on this account a larger gland has been assigned, which renders their necks more even and beautiful."

Verheyen, writing about 1720, describes the thyroid as deriving its name from the cartilage so called, and states that it is considered by some as double, *i.e.* consisting of two glands. He says, "this gland, beyond doubt, serves also to moisten the neighbouring parts; but, because it is very large, there is an apparent reason why it should have rather large excretory ducts, or one at least very conspicuous, which yet hitherto has not been discovered."

About 1708, Evertzen wrote an inaugural dissertation on the thyroid gland, noticing its structure, some diseases to which it is liable, and their treatment.

Morgagni, in his Advers. Anat. (1723) discusses two questions respecting the thyroid; one as to whether the gland is double or single, *i. e.* whether the lobes are connected by an isthmus or not; this he decides, as respects man, positively in the affirmative. The other *vexata questio*, as to whether the thyroid be provided with a duct or not, he confesses to be yet undetermined. He notices the existence of vesicular cavities in enlarged thyroids, which he justly supposes to be the natural cavities (nativi acini) dilated by their accumulated secretion. From his examination of the secretion of the thyroid, "mollem quendam, et obliniendo lubricandoque idoneum, succum communi isti amygdalarum oleo longè consimilem;" and from observing the thyroid to be exposed to the pressure of contracting muscles, as is the case with some other undoubted glands, he inclines to consider it probable that the gland has some duct

* Advers. Anat. i. c. 26.

† Lib. vi. cap. 4.

opening into the pharynx, the œsophagus, or into the top of the trachea.

Santorini (Observ. Anat. 1754), recognizes the thyroid as a single gland, and makes mention of its median column as previously known to Morgagni, though it was probably discovered by Bidloo or Lalonette. He details the failure of his efforts to discover a duct, though he had several times detected an orifice at the anterior angle of the glottis, into which a bristle could be passed; and yet remarks that the thyroid gland may be urged to expel its secretion by the pressure of the sub-hyoidean muscles, the throbbings of the carotids, and the contractions of the œsophagus.

Haller (Element. Physiolog. 1766), in his account of the thyroid, gives a good description of the median column, and of the several varieties which it presents; four times only has he found it absent; most frequently existing on the left side; sometimes, however, on the right. He relates some experiments of Lalonette, in which it appeared as if the glandular cavities had been distended by inflation with air, and *also the lymphatic vessels proceeding from them.* The result of this coarse proceeding he explains, and probably correctly, by supposing that the distended cavities were those of the areolar texture, and not the secreting vesicles. He remarks that, even according to Lalonette's testimony, no secretion can ever be pressed out of the thyroid gland into the cavity of the larynx; or if any appear it seems to be nothing more than the contents of some mucous follicles. After detailing the struggles and efforts of various anatomists to discover an efferent duct, he states at last that several inquirers, among whom he mentions Ruysch in particular, had adopted the only possible remaining opinion, that a peculiar fluid was elaborated in the gland, which being received into the radicles of the veins, was returned into the blood. This view, which laborious, and thoughtful, and sagacious men were then slow to entertain, is now universally adopted; and it seems certainly a matter of wonder that it was not sooner arrived at. May we not, however, question whether, in regard to other glands, a process somewhat similar does not also occur, —whether certain complementary products of secretory action are not formed in the gland, and afterwards absorbed and carried off by venous and lymphatic radicles?

Meckel's description of the thyroid is as complete as could be accomplished by the most consummate anatomical skill, while unaided by the achromatic lens. I need not refer to his well known pages, further than to notice a suggestion which he offers, viz., that as the median column is much more developed in the infant than in the adult, the excretory duct may exist at that period (in the median column), and become obliterated as age advances.

In proceeding beyond this period, we come to the anatomists of our own day; several of whom have advanced our knowledge considerably respecting the thyroid and other ductless glands. To none, however, are we more indebted than to Mr. Simon; whose masterly and philosophical Essay on the Thymus contains the best account of the anatomy and physiology of these organs that has yet been given.

Bibliography.—*Wharton,* Adenographia. *Morgagni,* Adversaria Anatomica. *Haller,* Elementa Physiologica. *Meckel* and *Cruveilhier's* works on Descriptive Anatomy. *Quain* and *Sharpey's* Anatomy. *Todd* and *Bowman,* Physiological Anatomy. *Simon's* paper in Philos. Transact. 1844, on Comparative Anatomy of Thyroid. Various parts of the essay of the same author on the Thymus gland. *Henle,* Allgemeine Anatomie. *Œsterlen,* Beiträge zur Physiologie.

(*C. Handfield Jones.*)

TIBIO-FIBULAR ARTICULATIONS.

— The bones of the leg, throughout the greater part of their length parallel and contiguous to each other only, are in contact by their extremities. At the points of contact the two tibio-fibular articulations, a superior and an inferior, are situated.

Superior Tibio-Fibular Articulation. —The head of the fibula is in contact with the external tuberosity of the tibia. The former is furnished with an articulating surface which has an aspect upwards, forwards, and inwards, whilst the articular facet on the latter is placed rather towards the posterior part of the tuberosity of the tibia, and is directed downwards, backwards, and outwards. Both surfaces are almost perfectly plane, their form is circular, and they are encrusted with articular cartilage; hence this articulation is to be referred to the class arthrodia.

a. The *ligaments* of this joint are two in number, named, from their relative positions, *anterior* and *posterior ligaments.*

1. The *anterior ligament* of the superior tibio-fibular articulation, is composed of a fasciculus of white fibrous bands, which are all parallel to each other. It passes from the tibia downwards and outwards to the head of the fibula, running in front of the synovial membrane of the articulation which it defends. The extensor digitorum communis muscle covers this ligament anteriorly.

2. The *posterior ligament* follows a similar direction on the posterior aspect of the joint; but the fibres which compose it are neither so numerous nor so strong as those of the preceding; this ligament is covered posteriorly by the poplitæus muscle.

Lastly, the *tendon of the biceps* (*flexor cruris*), by its attachment to the head of the fibula, contributes, in no inconsiderable degree, to the security of the articulation.

b. *Synovial membrane.*—There is nothing, in the anatomical disposition of the synovial membrane of this articulation, which requires any particular notice; but the surgeon should remember that it is always in close proximity to the serous sac of the knee joint, and that in many instances the two synovial membranes communicate with each other. The synovial membrane of the knee joint is brought into this close relationship with that of the tibio-fibular articulation, by means of a prolongation which passes downwards from the former around the tendon of the poplitæus muscle; and when a communication does exist between the two articulations, it will therefore be found at the posterior aspect of the head of the fibula.

This anatomical arrangement has an important bearing on a disputed point of practice, viz. the extirpation of the head of the fibula in amputations of the leg near the knee joint. This proceeding, recommended originally by Larrey and Garriques, and subsequently revived by Mr. Guthrie, has been opposed by Mr. Adams of Dublin, who, appealing to the anatomical peculiarities just described, makes them the grounds for rejecting altogether the innovation in question. (*Vide* "ABNORMAL CONDITION OF THE KNEE JOINT," vol. iii. p. 50.)

INFERIOR TIBIO-FIBULAR ARTICULATION. —This articulation is intimately connected with that of the ankle, from which, although anatomically distinct, it cannot virtually be separated.

The tibia and the fibula, at the lower part of the leg, are closely connected for a considerable portion of their extent. The tibia presents, on its external aspect and inferiorly, a triangular-shaped surface, two inches in vertical height, and concave from side to side: *superiorly*, or towards the apex of this space, it presents a rough and scabrous surface; but *inferiorly* it is smooth and encrusted, in the recent state, with articular cartilage. The inner surface of the lower end of the fibula is of similar shape, but convex; it is rough superiorly, and smooth inferiorly. Here the two bones form an arthrodial articulation.

a. The *cartilage*, which in this situation invests the opposed surfaces of the tibia and fibula, is continuous with that which covers the inferior surface of the tibia. It is also lined by—b.—*synovial membrane* prolonged upwards from the ankle joint, and which forms a small cul-de-sac in the tibio-fibular articulation. The rough irregular surfaces, on the bones above the line of reflexion of the synovial membrane, have the fibres of a strong interosseous ligament implanted into them.

c. The *ligaments* of the inferior tibio-fibular articulation are three in number; 1. *an anterior*, 2. *a posterior*, and 3. *an interosseous.*

1. *Anterior tibio-fibular ligament.*—The fibres of this ligament pursue a direction downwards and outwards, from the anterior margin of the small articulating surface on the tibia to the outer malleolus; and as the lower margin of this ligament projects below the level of the tibia, it deepens somewhat the cavity for the reception of the astragalus. The tendon of the peronæus tertius muscle covers this ligament in front.

2. *Posterior tibio-fibular ligament.*—This is a strong, round, fibro-cartilaginous cord, which passes from one malleolus to the other in an arched manner, having a concavity directed downwards, and connected with the posterior ligament of the ankle joint, and a convexity which adheres uniformly to the posterior articular margins of the tibia and fibula. This ligament not only connects the two bones to each other, but it also, like circumferential fibro-cartilages elsewhere, serves the purpose of deepening the mortice-shaped cavity of the ankle joint which it borders. It likewise prevents the immediate contact of the osseous surfaces in forced extension of the foot, being interposed between the bones as an elastic cushion.

3. *Interosseous tibio-fibular ligament.*—This is composed of short transverse bands firmly implanted, at right angles, into the opposed rough surfaces on the bones already described. *Superiorly*, the fibres of this ligament extend nearly as far as the lower margin of the *interosseous membrane*, (separated from it by a small interval, through which passes a branch of the fibular artery), whilst *inferiorly* they are limited by the direct contact of the two bones of the leg, which they serve to bind firmly together. In order to exhibit this structure, either of two methods may be adopted; the bones of the leg may be sawn across about their centres, and then forcibly torn asunder, (in this way the ligament may be seen, and its powers of resistance appreciated), or the ligament may be exhibited *in situ*, by making a vertical, transverse, section of both bones, traversing the two malleoli, and also the joint of the ankle.*

Mechanism of the tibio-fibular articulations. —The movements of the fibula on the tibia are extremely limited; this is in accordance with the general plan on which the skeleton of the lower extremity is formed, its use being to serve as an organ of support, and of locomotion, only. The bones of the leg are connected together by the intervention of ligaments, (not consolidated together as in the arrangement met with in a few of the Mammalia), and thus a greater degree of elasticity is obtained without any sacrifice of strength; and it may be presumed that the slight degree of yielding and of gliding motion, which is permitted in the tibio-fibular articulations, may occasionally serve to diffuse, and to lessen the intensity of shocks applied to the lower extremity, and may thus diminish its liability to injury, especially to fracture.

Dislocation of the fibula, at the *upper tibio-fibular articulation*, has occasionally, but rarely, been met with as the result of injury. Sir A. Cooper mentions a case of compound fracture of the tibia, where this complication was observed; but the rarity of dislocations in this situation, is accounted for by the circumstance, that the fibula, owing to its comparative slightness, almost invariably breaks, on the application of a force far short of what suffices to rupture its ligamentous connections with the tibia.

The mechanism of the *inferior tibio-fibular articulation* is inseparably connected with

* See fig. 61. p. 163. vol. i.

that of the neighbouring articulation of the ankle. In fact, on the perfect adaptation of the bones of the leg, at their lower extremities, essentially depends the integrity of the ankle joint itself.

By the union of the tibia with the fibula the "mortice shaped" cavity, which receives the pulley of the astragalus, is formed, and any injuries which disturb the natural relations of these two bones interfere proportionally with the functions of the ankle, which is a perfect angular ginglymus.

Hence it is, that in some cases of fracture of the lower end of the fibula, a widening of the mortice is produced, from which more or less of permanent deformity and inconvenience results, abnormal lateral motion being then permitted. The connecting media between the tibia and the fibula inferiorly are of extreme strength; so much so, that no ordinary violence seems capable of rupturing them; the bones being bound together, not only by the special ligaments of the inferior tibio-fibular articulation already described, but by the annular ligaments and fasciæ of the leg also. Hence, as we might infer, the separation of these bones by injury has never been observed, except when the fibula has first been broken. In the "*complete* dislocation of the foot upwards and outwards, we are furnished with an illustration of the immense strength of the interosseous ligament; as it is found that even in this severe injury the fibres of this ligament are not usually torn; but the rough surface of the tibia into which they are implanted is broken off, and carried upwards and outwards with the lower end of the fibula, to which the interosseous ligament still binds it." (See *b. fig.* 54. vol. i. page 157; article "ABNORMAL CONDITIONS OF THE ANKLE JOINT.")

(*Ben. George M'Dowel.*)

TONGUE. (Γλῶσσα, Gr.; *Lingua*, Lat.; *la Langue*, Fr.; *Zunge*, Germ.; *Lingua*, Ital.) The tongue is a symmetrical muscular organ, situated in the middle line, at the orifice of the gastric portion of the gastro-pulmonary mucous membrane, invested with the mucous surface, and subserving to the early stages of the process of digestion.

HUMAN ANATOMY. — The human tongue (in common with that of all mammalia) consists of, first, an osseous basis, itself movable, to which it is attached, and with which and on which it moves; secondly, a muscular system, in part *extrinsic*, serving to attach it to certain fixed points and to move it on them, and in part *intrinsic*, constituting the bulk of its substance and moving it on itself; thirdly, a mucous investment, variously modified in different parts; fourthly, a proper system of mucous glands; fifthly, a small quantity of fibrous and areolar tissue; sixthly, a still smaller quantity of fat; seventhly, a large vascular supply; and eighthly, an abundant distribution of nerves from three separate sources.

Size. — The size of the tongue is very various. I have examined some tongues of adults that certainly were not more than half the size of others, and there does not seem to be any relation between the size of the tongue and that of the individual; but between it and the size of the alveolar arch there is a close relation, and hence we see it generally much smaller in women than in men. It has been generally stated that certain obscurities in speech are caused by too large a tongue, but there do not seem to be any well authenticated cases to prove that this supposition is correct. It may in some degree be explained by the fact, that paralysis, which would cause a thickness of speech, would also cause a flaccid half-protruded condition, and, therefore, an apparent increase of size, of the tongue.

Direction. — In its anterior half it follows pretty much the direction of the lower jaw, that is, it tends forwards and a little downwards, but behind this it curves downwards and backwards, and ere it reaches the os hyoides has become quite vertical, so that the average of its direction would be downwards and backwards, and its posterior extremity much lower than its anterior.

Shape. — The tongue is of an ovoidal shape, the broad part being behind; and the character of the curvature in front is parabolic, coinciding with the parabolic curve of the lower jaw: it possesses an exact lateral symmetry, and is flattened from above downwards, being thickest towards its base, and thinnest in front. When taken out of the body it seems to be flat, and in the same plane longitudinally, but when *in situ* it possesses a double curvature; one longitudinal, the most considerable, by which the upper surface is rendered convex, and by which the posterior part of the tongue is bent from a horizontal to a vertical direction; the other, less considerable, affects the tongue transversely, and renders its posterior part concave in that direction: it is much increased by the contraction of the genioglossi, which draw the centre of the tongue down, or by that of the styloglossi, which draw its sides up. The longitudinal curvature, too, is very much affected by the position of the tongue, for when it is thrust forward, and the hyoid bone raised, the whole organ is much more horizontal, and the curvature almost effaced.

General description. — In consequence of its possessing a long axis, and being vertically flattened, the tongue presents for description a *superior* and *inferior surface*, two *lateral borders*, and an *anterior* and *posterior extremity.*

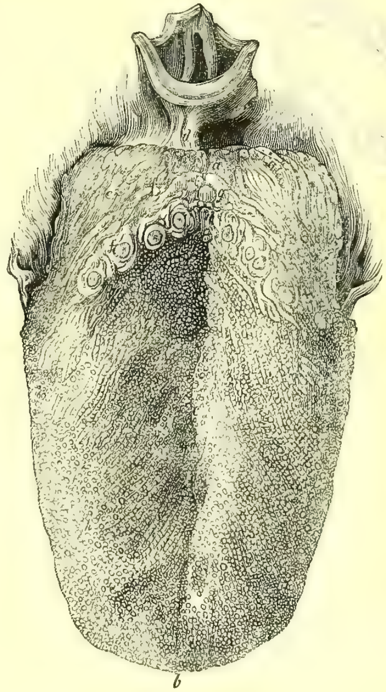
The superior surface, borders, anterior extremity, and anterior third of the inferior surface are free; the posterior extremity and posterior two thirds of the inferior surface are attached. Along the line where the free and attached surfaces meet, we see the investing membrane leaving the tongue, and passing off to neighbouring structures, investing the loose areolar tissue by which in these situations it is underlaid, and forming a system of yielding and movable attachments. Thus at the base the mucous membrane passes off to the anterior surface of the epiglottis, the sides of the pharynx, and upwards to the soft palate and posterior parts of the cheeks. As we proceed forwards we find it investing the sides, and gradually more and more of the under surface, reflected thence over the hyoglossi and genioglossi muscles, the sublingual glands, vessels, and nerves, and much areolar tissue, which separate it from the mylohyoid muscle, to the inner surface of the alveoli of the lower jaw, where it becomes continuous with the mucous membrane covering the gums.

At certain points where this membrane leaves the tongue it forms distinct folds, which, from their being constant, have received particular names, and which act to a certain extent as ligaments or *frena* of the tongue, not so much by virtue of their being folds of mucous membrane, as from their containing within their reduplications a certain amount of a more or less unyielding tissue; in some this tissue is a mixture of white and yellow fibre, in others it is muscle.

Of the first sort are three folds, a middle and two lateral, passing from the base of the tongue to the epiglottis, called the *glosso-epiglottid folds*, of which the central, which is always present, and has been called the *posterior frænum* of the tongue, and *frænum epiglottidis*, is much the most considerable (*fig.* 745. *d.*): they serve rather to check the movements of the epiglottis than as lingual ligaments. From the sides of the base of the tongue, passing thence to the soft palate, are seen four more folds, two on each side, which, from their position, have been called the *pillars of the fauces*. They are formed by the raising of the mucous membrane from the general surface by two muscles: the posterior, the least considerable, by the palato-pharyngeus; the anterior, more marked, by the palatoglossus. The interval between these two is called the *amygdaloid fossa*, from its being occupied by the amygdalæ, or tonsils: the anterior pair taken together constitute the constrictor of the fauces, and the narrowing caused by the whole apparatus has received the name of the *isthmus faucium*. From the basis of these folds being muscular their prominence is liable to constant variety. But the most considerable of these folds, which is called, *par excellence*, the *frænum of the tongue* (*frænum, frenulum linguæ*), is placed beneath the anterior free extremity, which it connects with the lower jaw. It consists of a prolongation forwards, beyond the free border of the genioglossi, of the median fibrous lamina, which raises into a prominent fold the mucous membrane passing from the under surface of the anterior part of the tongue to the neighbouring alveoli of the lower jaw: it forms a strong ligament, and limits the backward movement of the anterior extremity of the tongue. Sometimes an extreme shortness of this ligament is a congenital malformation, preventing the free movement of the organ, and so impairing speech, mastication, &c., as to necessitate the operation known as *cutting the tongue*.

Before entering into the specialities of the anatomy of the tongue, let us examine its

Fig. 745.



Human tongue viewed on the upper surface or dorsum. (After Sœmmering.)

general configuration and external characters, taking its surfaces, extremities, &c., in the order above enunciated.

Superior surface.— On regarding the upper surface of the tongue, we see first that it is divided into two symmetrical portions by a *median longitudinal furrow* (*fig.* 745. *c.*), commencing at the tip, and extending back about two thirds the length of the organ. It is superficial when present, but in many cases does not exist: it is the representative, in this part, of that median line which symmetrically divides all those organs of animal life that are situated in the middle vertical plane. It is very generally, but very incorrectly, stated* that this furrow terminates posteriorly in the foramen cæcum. The two have no relation; the one often exists without the other; and in every case that I have seen, the foramen has been separated from the posterior termination of the furrow by the ridge of the circumvallate papillæ, sometimes by a long interval. This median furrow seems partly formed by the action of muscles, and partly by a deficiency of papillæ. Another conspicuous character of the upper surface is, that the roughnesses with which it is covered are arranged in lines (*fig.* 745.), with a direction obliquely forwards and outwards, so

* Bichat, Traité d'Anatomie, t. ii. p. 594.

that there is formed in the median line a series of angles pointing backwards. This disposition is seen to affect, more or less, all the structures with which the surface is covered. Thirdly, the upper surface of the tongue is seen to be divisible into a *smooth* and a *rough* portion. The smooth, or non-papillary portion, occupying nearly the posterior third, is characterised by smooth nodular rugosities (*fig.* 745. *e*), formed by small muciparous glands, which are abundantly distributed beneath the surface, and occupy the whole space between the papillæ and epiglottis: they are smallest and most scattered behind, where they are gradually lost; larger and more prominent in front, where, from their being disposed in the direction already indicated, they form a prominent V-shaped ridge with the opening directed forwards. Just in front of this, separated by a groove, is another V-shaped ridge, more definite, but less constant in shape, formed by two converging lines of button-like eminences, each surrounded by a circular raised border of more or less regularity; these compound organs are the *circumvallate papillæ* (*fig.* 745. *f f*). At the angle formed by the convergence of their two rows, generally a little behind that angle, is situated a cul-de-sac of very variable size, which has received the name of *foramen cæcum* (*le trou borgne*, *lacune de la langue*), and which was formerly regarded as the orifice at which several convergent salivary ducts terminated*; these supposed salivary ducts were afterwards shown by Duvernoy† and Haller‡ to be merely small veins. Meckel considered that this foramen cæcum was nothing but a largely developed calyx of a caliciform papilla, of which the central portion was small, or wanting, or misplaced; that if the central eminence was well developed and in its proper situation, the foramen cæcum was wanting, and that it only existed from some of the irregularities above mentioned; an opinion adopted by Cruveilhier, and by Professors Todd and Bowman in this country. Meckel states that he has seen two, one a great way behind the other. I have more than once met with the same appearance. In these cases the anterior one has always contained a well developed papilla. It can evidently perform no essential office, as it is so often wanting. The whole of the superior surface of the tongue, in front of the circumvallate papillæ, comprising its anterior two thirds, is covered by an investment of coriaceous or filamentous asperities, longest in the central parts, and arranged with the most regularity at the back, where they are distributed in lines of more or less distinctness, with a direction obliquely forwards and outwards (*fig.* 745. *i i*). These eminences are seen to be of two sorts; one of a spheroidal shape, distinguished during life by their red colour, and scattered here and there at the posterior part, edges and tip, — these are the *fungiform papillæ* (*fig.* 745. *h*); the others, occupying the whole of the rest of the surface, are the *conical* and *filiform*. To the minute consideration of these structures a future part of this article will be devoted.

* Coschwitz, De Ductu salivali novo. Halle, 1724.

† Loc. cit.

‡ Exp. et Dub. circa Ductum Coschw. Leyden, 1727.

Inferior surface. — This surface is attached in its posterior two thirds by the muscles passing from it to the hyoid bone and lower jaw. The most posterior part of this attachment is as wide as the tongue itself, so that there no portion of the inferior surface is free; but in front of this the attachment narrows, so that the lateral portions become increasingly free till they meet at the frænum, in front of which they involve the whole surface. The longitudinal furrow is much more distinctly marked here than above, and is constant: it passes from the tip, on which it is continued, to the frænum. On each side of the furrow the ranine veins are seen passing forwards, and immediately beneath the tip is a little cluster of mucous glands first described by Nuck*, and also by Nuhn.† The mucous membrane here is quite smooth and free from any visible papillæ.

The *edges* of the tongue, which separate its upper and under surface, are thick behind and gradually become thinner in front; they are marked by a series of vertical ridges, separated by corresponding furrows, very distinct on the upper, and gradually becoming lost as they approach the under, surface. They are very conspicuous at the posterior part, but disappear anteriorly, and they differ very much in their development in different subjects. They are, essentially, fused conical papillæ. At the upper and posterior part of the edges are also a series of small mucous glands.

The *anterior extremity, apex*, or *point* (*fig.* 745. *b.*), is flattened or rounded, blunt or pointed, according to the movements of the tongue, and slightly impressed by the median furrow which is continued on it: it is not marked by any of those vertical ridges that characterise the edges.

The posterior extremity, or base. — Ere the tongue reaches the os hyoides it becomes very flat and thin, and this from two causes — diminution in the quantity of the intrinsic muscles, and the passing off of the extrinsic in other directions; so that instead of being very thick, as is generally described, the base is in reality the thinnest part of the whole organ. It is flattened antero-posteriorly and much extended laterally, and by its attachment to the hyoid bone is curved in a horseshoe shape, which, however, is much effaced by the insertion of the epiglottis in the area of the curvature. It is constituted laterally by the hyoglossi, centrally by the hyoglossal ligament, anteriorly by some fibres of the genioglossus, and behind and above by the mucous membrane passing from it over the

* Sialographia, Ductuum aquosorum anatome nova. Leyden, 1690.

† See Art. SALIVARY GLANDS, p. 426.

epiglottis. It contains less muscular and more fibrous tissue than any other part of the tongue.

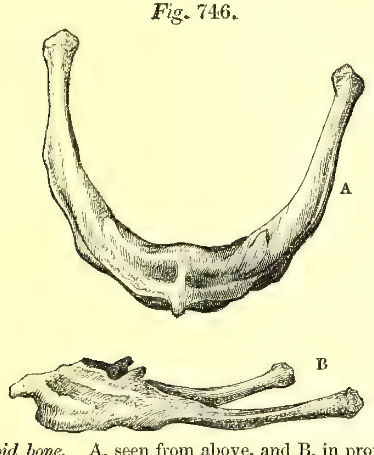
Such, then, is a general description of the tongue, — such are the appearances that present themselves to the eye, on regarding its external surface and configuration. Let us now examine these structures more minutely, and, to facilitate that examination, arrange the parts that contribute to the formation of the organ, according to the office they fulfil, or their absolute nature.

Regarding the tongue in this light, we find that it may be considered as consisting of three systems, —

1. *A basis*, or system of support.
2. *A muscular system*, or system of movement.
3. *A tegumentary investment*, or system of sensation and protection.

1. *Basis, or framework of the tongue.*—This consists of the hyoid bone, the hyoglossal membrane or ligament, the median fibrous septum (the cartilaginous lamina of M. Blandin), and, fourthly, to these may perhaps be added, on account of its density, and its giving attachment to most of the intrinsic muscles, the compact fibrous tissue, or cutis, beneath the mucous membrane.

Fig. 746.



Hyoid bone. A. seen from above, and B. in profile. (*Natural size*).

a. The *hyoid bone* (os hyoides, —upsiloïdes, —lingualis,— linguæ), called also the *lingual* or *tongue bone*, has received its name from its resemblance to the Greek υ; it is the homologue in man of a very complex mechanism in the lower vertebrata, from which circumstance it is sometimes called the hyoid *apparatus*. It consists of a bony arch, with a curvature nearly approaching a parabola, the convexity being in front; — situated in an almost horizontal position behind and rather below the lower jaw. In the lower vertebrata the hyoid bone is connected to the rest of the skeleton by bony media; in man, by the substitution of a ligament (the stylohyoid) for a part of this osseous connection; it is isolated, and disconnected from all the other bones.* It performs the triple office of a basis of the tongue, a point of support to the larynx, and a *point d'appui* or fulcrum, by which the contractions of the intrinsic muscles of the tongue and larynx may be impressed on those organs: it may also be looked upon as the first part of that framework (afterwards generally continued by cartilage) which secures the permanent patulence of the respiratory passages. It is retained in its place by muscles and ligaments, which, converging to it from different directions, effectually prevent its displacement: thus it is tied upwards and backwards by the ligament and muscles from the styloid process, in front by the muscles from the chin and lower jaw, below by those from the thyroid cartilage, sternum, and scapula. Placed between the tongue and larynx, it impresses on each the movement of the other, and is the medium by which the motions of these two organs are so intimately associated.

Relations. — Its whole external surface is devoted to muscular insertions, which separate it, anteriorly and laterally, from the cutaneous structures. Behind, it is in relation with the epiglottis, from which it is separated by some dense cellular tissue, and by the thyrohyoid membrane, and with the mucous membrane of the pharynx.

In man the hyoid bone consists of five pieces, — the *basis* or *body*, two *greater cornua* which project backwards from the sides of the body in a direction nearly horizontal but a little upwards, and two *lesser cornua*, surmounting the body and greater cornua at the point of their union.

The *body* is quadrilateral, compressed antero-posteriorly, curved, and laterally extended. Its anterior surface looks upwards, is convex, and intersected by two irregular ridges, a vertical and horizontal, which at the point of their union project in a prominent tubercle, which is the analogue in man of an additional element of the hyoid apparatus in the lower animals — the true lingual bone (*glossohyal*): this tubercle is sometimes bifurcated. The portion above the transverse ridge is directed much more upwards than that below, so that it has sometimes been called the upper surface: in that case the portion below is described as the whole anterior surface, a circumstance which has led to much confusion with regard to the nomenclature of muscular insertions into this bone. The posterior surface is concave, and looks downwards; it is marked by many little foramina entering the cancellous structure, and is sometimes covered by a synovial membrane. The lateral surfaces, small and articular, are connected to the anterior extremities of the greater cornua by a lamina of temporary cartilage, which, however, is seldom completely ossified, and which admits a certain amount of movement between the different

* In some rare cases this ligament has been ossified, and then the condition of the os hyoides is the same as that found in most quadrupeds, fish, and reptiles.

parts. The superior border presents a double curvature, something like the upper lip of the mouth, *i. e.*, it curves downwards at its extremities, and has a little dip in the middle. The inferior border, of less extent, is thinner, horizontal, and placed on a plane anterior to the upper.

The *greater cornua* are at least half as long again as the body, from the sides of which they project, at first a little outwards and then backwards; they possess a *shaft* and *two extremities.* The anterior extremity is large, club-shaped, tuberculated, and curved inwards towards the body, for its attachment with which it presents an articular facet; the shaft tapers gradually posteriorly, and is laterally flattened, so that it has an *outer* and *inner surface,* and an *upper* and *lower border.* Its outer surface, which is continuous with the anterior surface of the body, looks a little upwards; its lower border is smooth and rounded; its upper border sharp, and, from the obliquity of the surfaces, of less extent than the lower. The posterior extremity is expanded into a little tubercle, sometimes surmounted by an epiphysis.

The *lesser cornua* (ossa pisiformia lingualia, of Sœmmering) are two little pyramidal or pisiform nodules, projecting upwards, outwards, and backwards, from the point of union of the greater cornua and body: they are seldom completely ossified. They are the homologues in man of a very considerable process (*the ceratohyal*) in the lower animals, in some of whom the proportion between the lesser and greater cornua is inverted.

Structure — Chiefly compact, but a little cancellous in the body and large extremity of the greater cornua.

Development. — From five points; one for each element. Vesalius saw a case in which there were six, there being two for the body. The ossification commences in the greater cornua; it then takes place in the body, where it begins soon after birth; and, finally, in the lesser cornua, where it does not commence till some months after. It proceeds but slowly, and generally leaves a thin lamina of cartilage unossified, so that complete anchylosis of the different parts into one bone is comparatively rare.

The morphological value of this bone and its homological relations, will be treated of hereafter.

b. The hyoglossal membrane or ligament. — This is a vertical transverse lamina of very dense areolar tissue, containing a large proportion of the yellow element, passing upwards from the upper border of the body of the os hyoides to the tongue, between which it constitutes a means of union. The muscular connection of the tongue with the hyoid bone by means of the hyoglossus is deficient in the central part of the body of that bone, and, consequently, this ligament is, in that situation, the only direct bond of connection. It is dense, yellow, and very elastic, and has a little fat dispersed among it, though this is denied by Bichat. It may be traced upwards into the tongue, sometimes as far as an inch. It receives on its anterior face those fibres of the genioglossus that lie immediately above those that are inserted into the hyoid bone, and also some of the intrinsic longitudinal fibres of the tongue that terminate upon it; posteriorly it is in relation with the upper part of the epiglottis and the mucous membrane reflected upon it from the tongue; in fact, it immediately underlays the glosso-epiglottid folds. Above, it is gradually lost in the muscles of the tongue; below, it in part terminates in the upper lip of the body of the os hyoides, and in part is continued on behind this bone, constituting the yellow elastic tissue already referred to as being interposed between it and the epiglottis. This ligament has been well described by Bichat.*

c. Median fibrous septum (*median cartilaginous lamina,* Blandin). — Springing from the anterior surface of the last-mentioned structure, interposed between the two genioglossi muscles, passing forwards between these two muscles as far as their genial origin, upwards to the dorsum of the tongue as far forwards as its centre, and thence to the anterior free border of the genioglossi, and a little beyond that border, is a vertical lamina of fibrous tissue. It is thick and dense behind and below, but gradually becomes thinned out as it spreads upwards and forwards; as it gets thinner it becomes cribriform, like the septum of the corpora cavernosa penis, the areolæ giving transmission to the transverse muscles of the tongue, which pass through it from side to side. It varies much in different individuals; in some it is tolerably dense, in some it is merely a fine areolar web. This structure M. Blandin has dignified with the name of "*median cartilaginous lamina,*" and has described it as consisting of a vertical sheet of that substance of more or less extent. I have, however, looked in vain for any thing like cartilage or fibro-cartilage in any part of it. It appears to me to be nothing more than intermuscular areolar tissue in rather greater amount and density than usual, which happens to be placed in the median plane. It has been supposed by some to be the analogue of the small fusiform slip of cartilage placed beneath the extremity of the tongue in the dog and wolf, with which, however, it has no relation: that structure is essentially distinct. Others have found in it the analogue of the lingual bone, a conception still more far-fetched. It has been supposed to give origin to muscular fibres by its two surfaces. This I have failed in detecting; certainly it does not give attachment to any of the *transverse* fibres of the tongue, to which it might be supposed it would, if to any; for they may be seen, by transverse sections viewed with the microscope, to pass, without exception, from side to side of the tongue, without any break in their median plane.

d. Lastly, the *investments* of the tongue, including the papillary structures and the true

* Traité d'Anatomie, t. ii. p. 596.

cutis underlaying them, may be looked upon, in one light, as a part of the framework of the organ. They form a dense and unyielding envelope, tending to preserve its shape and give it firmness and support, and at the same time affording attachment to a great number of its muscular fibres.

Such, then, is a concise description of the framework of the tongue. The first and last-mentioned elements of it are, doubtless, the most important; but it will be seen, at a future page, that the intrinsic arrangement of the tongue's muscular fibres is such that they mutually support each other, and tend to keep the organ firm and compact, which obviates the necessity of any considerable structures especially destined for that purpose.

2. *The muscular system.* — Constituting the chief bulk of the tongue, imparting the required consistence to it, performing the majority of its functions — prehension, mastication, deglutition, speech,— and necessary even to the perfection of taste, the muscular system of the tongue may be considered the most important of all.

The muscles of the tongue are of three sorts, and admit of the following arrangement:

a. Intrinsic.
b. Extrinsic.
c. Accessory.

The *intrinsic* muscles are those which form the substance of the organ, that pass from part to part of it, and that move the tongue on itself.

The *extrinsic* (*proper*) are those that, as well as entering in some degree into the substance of the tongue, pass from it to neighbouring fixed points, to which they attach it, and on which they move it.

The *accessory* are those which, though not contributing in any degree to the formation of the tongue, nor attached to it, are yet engaged in all its extrinsic movements, acting as coadjutors to those proper extrinsic muscles whose direction coincides with theirs.

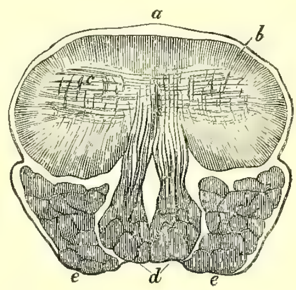
Of the two first I shall speak particularly: little more than their enumeration will suffice for the last.

a. Intrinsic muscles of the tongue. — There are three methods of investigating the arrangement of the tongue's intrinsic muscular structure: first, by the ordinary method of dissection, or separation; secondly, by making sections in different planes, and examining the appearance of the cut surfaces; thirdly, by the microscopic examination of thin sections. The first, which is the oldest, is that by which we gain the least information; and to its adoption must be attributed the fact that so many of the older anatomists were in the dark on this subject. By it we merely learn the following facts: that certain of the extrinsic muscles pass into the substance of the tongue and contribute to certain of the intrinsic; that the direction of most of the superficial fibres is more or less longitudinal; that the direction of the more deep-seated fibres is *not* longitudinal; that it is complex, and incapable of demonstration by separation.

The second method furnishes much more certain information. By making the sections in different planes, we vary the point from which we regard them; and the section made in one plane corrects, and supplies the deficiencies of, the other. The transverse vertical section is the most important; and to this I shall chiefly refer.

On making a *transverse vertical* section of a human tongue, at a point just behind the anterior free margin of the genioglossus (*fig.* 747.), the following are the appearances. Immediately within the cutis, which is seen to be tolerably thick, especially at the centre of the dorsum (*fig.* 747. *a.*), is seen a dark red stratum,

Fig. 747.



Transverse vertical section of human tongue just behind the free portion.

a, upper surface, showing the thickness of the cutis there; *b*, cortical portion; *c*, central portion, where the vertical fibres are seen crossing the transverse; *d*, genioglossi muscles; *e e*, sublingual glands.

also thick in the last-mentioned situation, thinner at the lateral regions, and again thicker as it curves inwards on each side of the inferior surface. This is very dense, and cuts with a perfectly even surface. I shall call it the *cortical* portion (*fig.* 747. *b.*). Within this and surrounded by it as by a border, is an area of a more or less oval form, of a paler colour, less dense, and showing a distinctly fibrous character. The fibres appear for the most part transverse (*fig.* 747. *c.*), horizontal in the centre, but curved up a little on each side. They are bounded on all sides by the cortical portion. Entering the centre of the bottom of the section, passing vertically upwards, crossing the last-mentioned fibres at right angles, and terminating in the superior surface of the cortical portion, are seen the two genioglossi muscles (*fig.* 747. *d.*). These, therefore, constitute a *vertical* set of fibres; but they are not the only vertical fibres; at each side of them, especially at the inferior portion of the section, other vertical fibres are seen passing upwards and a little inwards, and intersecting the more lateral portions of the *transverse* at right angles.* Cruveilhier has erroneously described them as passing *downwards* and *inwards*: their divergence as they pass downwards is very conspicuous. The central area — the *lingual nucleus* (*noyau lingual*) of Bauer, — is therefore constituted of two sets of fibres, a ventrical and transverse; the transverse being entirely intrinsic, and the vertical in part intrinsic and in part derived from the genioglossus.

A section made anterior to the free margin of this last-mentioned muscle, shows the cortical portion continued completely round the tongue, without the break on its inferior surface, occasioned, in the previous section, by the entrance of the genioglossi muscles; it is also of greater thickness in proportion to the central part, which is comparatively small, and the transverse fibres have a less marked upward curvature at their extremities.

Thirdly, a section made near the base of the tongue shows the cortical portion nearly lost at the upper surface, greatly accumulated at the sides, but not of so compact a nature as in more anterior situations; the obliquely vertical fibres tolerably abundant, but the transverse nearly lost, and the greater part of the inferior surface occupied by the expanded genioglossi.

Transverse vertical sections, therefore, display two sets of fibres, a vertical and a transverse, and shew their situation and quantity; let us now see what additional light will be furnished by a *longitudinal* vertical section. It shews that the cortical portion consists of *longitudinal* fibres, and thus supplies a third set. If the section be made in the middle line, or near it, the whole cut surface is occupied by the vertical fibres of the geniohyoglossus, at first directed backwards, but curving upwards so as to enter the tongue vertically, in which vertical direction they are continued up through its entire thickness, and are lost in the longitudinal fibres of the cortical portion; if the section is made in the lateral portions, it shows the vertical striation occasioned by the *intrinsic* vertical fibres, and the cortical portion, as in the other. Having ascertained the situation and direction of the three sorts of fibres, we may, by making transverse sections at all points from the apex to the base, and longitudinal ones at various distances from the vertical median plane, and also by tracing the extrinsic longitudinal muscles into the intrinsic, and seeing what part of the one the other furnishes, get an exact interpretation of them. We should then find the tongue to consist of the following muscles.

α. A *transverse lingual*†, altogether intrinsic, inserted on each side into the submucous fibrous tissue or cutis, continued from apex to base, more abundant anteriorly, where it is horizontal, becoming more curved upwards as we proceed backwards, and being lost at the base.

β. A *vertical lingual*, in part intrinsic; in part the lingual portion of an extrinsic muscle, the genioglossus, existing from apex to base, in all parts vertical to the surface, and therefore, from the curved direction of the tongue, arranged in a more or less radiating or fan-like manner.

γ. A *superior lingual*, longitudinal, intrinsic, thin behind, thicker in the middle, and thinner again at the apex, arising from the hyoglossal membrane and cutis at the base of the tongue in a gradual way, and having a similar cutaneous insertion on the upper surface of the tip and neighbouring parts.

δ. A *lateral lingual*, longitudinal, altogether extrinsic in its origin; derived from two principal sources; one, its upper and most superficial portion from the fibres of the styloglossus, which pass forward on the side of the tongue after the insertion of that muscle into it, the other from the anterior fibres of the hyoglossus which have a similar distribution: to this may be added a slender fasciculus of fibres interposed between the styloglossus and hyoglossus, which many modern anatomists* have described as the lingual muscle. The muscle thus formed constitutes the accumulation of longitudiual fibres before referred to as seen at the sides of a transverse vertical section of the base; passing forwards they become fused together and spread out so as to constitute a thin layer, merging above by converging towards the medial plane of the dorsum, in the *superior lingual*, below in that next to be described, and forming with them a sheath of longitudinal fibres, investing the whole surface of the tongue.

ε. An *inferior lingual*, a stout fasciculus of longitudinal muscular fibres entirely intrinsic, arising at the base of the tongue between the hyoglossus and genioglossus, and passing forwards between these two muscles to be inserted gradually into the cutis of the tongue on the inferior surface near the apex. This is the true *lingual* muscle of Douglas and Albinus, and of anatomists of the present day. I am doubtful whether or not the most anterior fibres of the genioglossus bend forwards so much as to become longitudinal, but I think not (though Cruveilhier says they do): if they do, the longitudinal sheath in front of the free margin of the genioglossus would consist of four sets, behind it of three.

Since the longitudinal fibres invest the whole of the free surface as a sheath; since they are, most of them, not directly, but obliquely, longitudinal; and since many of the central spread out to the sides, while the lateral converge to the centre, the division of the *longitudinal linguals* into *superior*, *lateral*,

* Theile denies the existence of the *intrinsic vertical* fibres; he says that those seen in longitudinal section are the ascending fibres of the genioglossus, and those seen besides them in transverse sections are the most oblique of the transverse; — a misconception of which the microscopical examination of sections at once shows the fallacy.

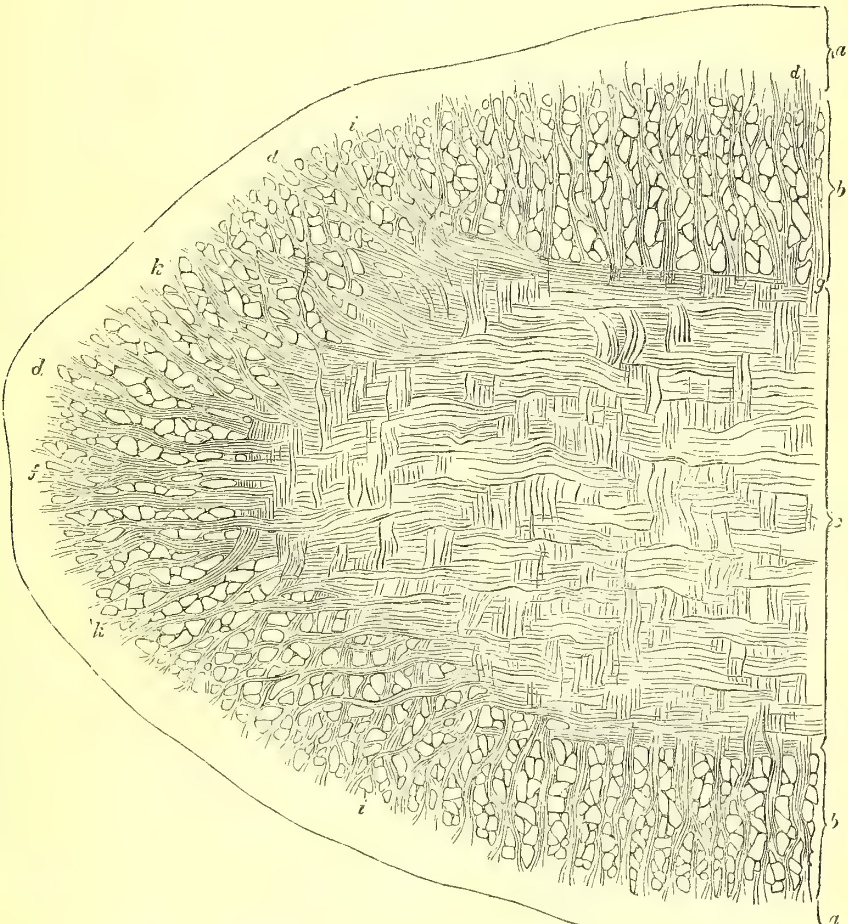
† The adoption of the word *lingual* for all the intrinsic muscles of the tongue, from the French writers on this subject, has no objection against it, and has the advantage of brevity.

* Bichat, Traité d'Anatomie, t. ii. p. 43.

and *inferior* must be to some extent arbitrary: however, most of those on the upper surface are intrinsic in their origin, those at the sides are extrinsic in their origin, while those on the inferior surface are sufficiently individual and distinct: some subdivision appears necessary, and the one adopted will at any rate assist in remembering these facts.

The microscopical examination of thin sections. On making a thin transverse vertical section of the human tongue, and examining it with the microscope*, we see that the appearances indicated by a similar section, viewed with the naked eye, are correct, namely, that the intrinsic muscular fibres assume three principal directions, a vertical, a transverse, and a longitudinal; and that the longitudinal are confined to the neighbourhood of the surface. But we see more; we see a very curious and artificial arrangement of the fibres very much contributing to facilitate their package, and by which they mutually support one another

Fig. 748.



Transverse vertical section of the left half of the human tongue at the most posterior part of the free portion. (Magnified 10 *diameters.)*

a, a, cutis; *b, b,* cortical portion, consisting of the three orders of fibres; *c,* central portion, consisting only of two; *d,* discs of longitudinal fibres, seen in section; *f,* horizontal median plane; *g,* line of emergence of the vertical from the transverse fibres; *i, i',* the most superior and inferior of the transverse curving up and down; *k, k,* the most lateral of the vertical curving outwards.

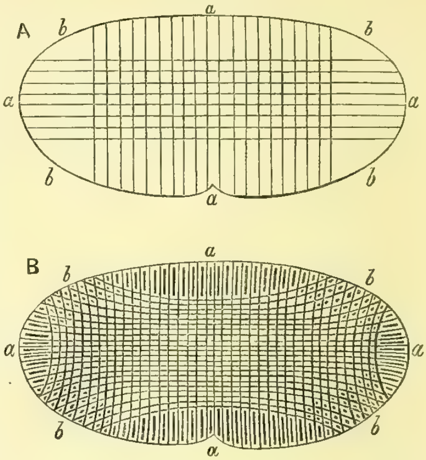
* The best method to adopt in making these investigations is to keep a fresh human tongue two or three days in spirit, and then boil it about an hour. On being first put into the boiling water it contracts and becomes very hard. When sufficiently boiled, let it dry in the air for a day, and then make the sections with some very thin flat knife. Place the sections on a glass slide with a drop or two of water, cover them with a piece of thin glass, and view them with an inch, or, if a very large field is wanted, a two-inch object-glass.

and act with the greatest advantage. This arrangement I shall now proceed to describe.

Suppose the section made at a point just in front of the anterior free border of the genioglossi (*fig.* 748.). Immediately beneath the papillæ (which may be very well displayed by this method), the condensed submucous areolar tissue or cutis of the tongue is seen, of considerable thickness, being thickest on the upper surface, especially towards the middle (*aa*). Immediately beneath this, around the whole circumference of the tongue, is seen a very curious areolated or fenestrated appearance, consisting of cross bars, branching and interlacing irregularly at various angles, leaving interspaces that are filled up by groups of discs (*dd*). The cross bars are at once seen to be small fasciculi of the vertical or transverse fibres, or both, according to the part looked at, and the groups of discs are seen to be transverse sections of the longitudinal fibres passing through the meshes formed by the vertical and transverse, which they more or less completely fill, and with whose shape they more or less exactly correspond (*figs.* 748. and 751.). The fasciculi of the longitudinal fibres are in most situations much larger than those of the vertical and transverse, among which they are contained; indeed, the longitudinal being confined to the surface, it would naturally be expected that they would preponderate there. The vertical fibres are most abundant in the vertical median plane and the horizontal in the horizontal median plane (*f*), the vertical not existing near the lateral surfaces, nor the transverse near the superior and inferior surface (*figs.* 749. *a*, *a*); and from this fact result almost all the peculiarities of arrangement of the fibres that we see.

In the *first* place it results from this, that the vertical and horizontal fibres cross each other in the centre, which they entirely occupy, and therefore exclude the longitudinal; accordingly no discs are seen in the central part of the tongue. *Secondly*, that at a certain line (*fig.* 748. *g.*) the vertical emerge from the transverse, and are continued up or down, to the superior or inferior surface, alone; and similarly at the lateral regions the transverse emerge from the vertical, and are continued on alone to the cutis at the sides; hence the fibres near the middle of the upper and under surface, and at the borders of the tongue, do not interlace but pass to the surface with something of parallelism; and hence the fasciculi of longitudinal fibres here are arranged, not as in the mesh of a network, but in parallel rows at right angles to the surface; an arrangement very characteristic of these situations. *Thirdly*, it would result from this absence of vertical fibres at the sides, and of the transverse above and below, that there would be four situations (*b*, *b*, *b*, *b*, *fig.* 749. A.) in the neutral ground between the upper and under surfaces and the borders respectively, where there would be no cross fibres of any sort, and where the longitudinal fibres would exist alone, unsupported and unseparated. Moreover, the vertical fibres at the upper and under surface, and the transverse at the sides, would be so dense and numerous that they would hardly admit of any longitudinal fibres in their interspaces. Now the support and separation of the longitudinal fasciculi, and the admission of a sufficient number of them at all the superficial parts of the tongue (especially the two surfaces and the two edges, which may be called the cardinal points of the tongue with regard to its movements), are the two things that are especially to be brought about. To achieve this double object, the vertical and horizontal fibres, as they approach their respective surfaces, spread out in a sort of fan-like manner; the most lateral of the vertical fibres spreading out towards the sides (*fig.* 748. *k*, *k*), and the most superior and inferior of the transverse spreading up and down towards the surfaces (*fig.* 748. *i*, *i*, *fig.* 749. B.). The two sets thus cross each other and fill the otherwise empty space with a network of considerable regularity and beauty, which is characteristic of these four situations, as the parallel fasciculi at right angles to the surface are characteristic of the four intermediate ones. For the sake of convenience I shall call the situations where the transverse and vertical fibres approach the surface in parallel bundles, the *superior*, the *inferior*, and the *right* and *left lateral* regions (*fig.* 749. A, B. *a*, *a*, *a*, *a*): those in which they decussate as they approach the surface, I shall call the *right* and *left supra-lateral*, and the *right* and *left sub-lateral* (*fig.* 749. B. *b*, *b*, *b*, *b*.). *Fourthly*, the mesial vertical and mesial horizontal plane are the situations where the vertical and horizontal fibres respectively would act with the greatest power on the form of the tongue, and where also they would admit of being the

Fig. 749.



Plan of the intrinsic muscles of the tongue as seen in transverse section.

a, *a*, *a*, *a*, Superior, inferior, right and left lateral regions; *b*, *b*, *b*, *b*, right and left supra and sub-lateral regions. (Compare with *fig.* 4.).

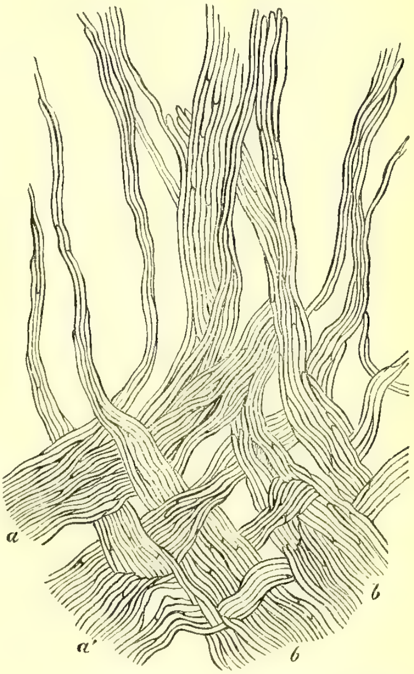
longest; hence we see the fasciculi in these situations much larger and more densely packed than in the intermediate positions, so that they more than equal the longitudinal fibres that they transmit. The extreme lateral fibres, on the other hand, that spread out and interlace, having little more for their office than to support the longitudinal fibres, are very small and scanty, many of them consisting of only a single fibre, and hence at these points the preponderance of the longitudinal over the vertical and horizontal fibres is the greatest. *Fifthly*, the most deep-seated of the longitudinal fibres of the upper and under surface are underlaid by a definite floor of transverse fibres, and similarly the deepest of those at the side are underlaid by a floor of vertical fibres; therefore in these situations there is a strong line of demarcation, the discs are abundant down to the bottom of the cortical layer, and there they terminate suddenly (*fig.* 751.); but in the intermediate positions there is no definite floor, no line of demarcation, but the discs of longitudinal fibres dip down at irregular distances (*figs.* 748, 749, 750.).

This is the general plan and rationale of the arrangement, but it is rather an exposition than a description, and it must be understood as merely referring to a transverse vertical section of the tongue, made at the most posterior part of the free portion of the tongue: there are often irregularities that make it difficult to recognise the plan, and, in some situations, certain disturbing forces, and superadded parts that quite upset its symmetry. For example, behind the anterior third of the tongue, the genioglossus is seen entering its inferior surface, and displacing all longitudinal fibres (*fig.* 747. *d*); further back, this displacement is more considerable, and we have similar infringements from other muscles; and the intermixture of fat towards the base of the tongue tends materially to upset the regularity of the muscular arrangement. Yet, in spite of this, it may always be detected, and the average of appearances will be such as I have described.

The muscular fibres are neither straight nor parallel; those of each system maintain their general direction, but their course is wavy and tortuous, and characterised by the utmost irregularity; as the fibres pass outwards they branch and sometimes re-unite (*figs.* 750, 751.), though their branchings are much more frequent than their re-unions, and hence the fasciculi are smaller and more numerous near the periphery than towards the centre (*fig.* 751.); by these branchings of the fasciculi each set of fibres, the vertical or transverse, possesses what may be called an *intrinsic* network, imperfectly marked certainly, but sufficient in some parts to mask their parallelism and to break up the rows of longitudinal fibres that are packed between them.

The number of fibres in each of the vertical or transverse fasciculi, varies according to the part of the section viewed, and the situation in the tongue from which it is taken; sometimes one single fibre constitutes the fasciculus, if one may say so, sometimes many dozen. Some of the largest are the most superior of the horizontal,— those that curve up on each side towards the upper surface (*fig.* 750.). The same variety of size exists in

Fig. 750.

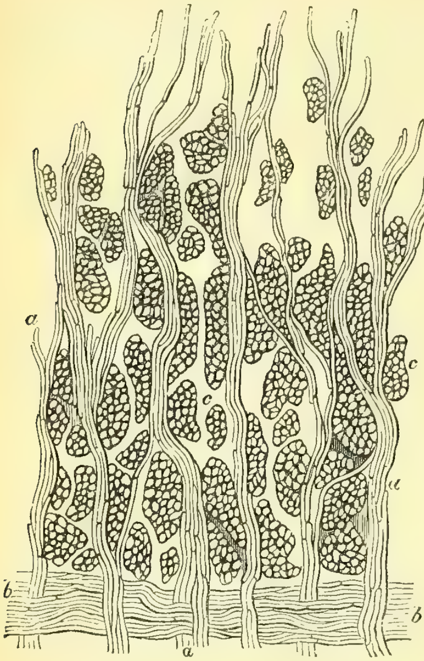


Portion of cortical layer of the right supra-lateral region of the tongue, showing the interlacement of *a*, *a*, the horizontal with *b*, *b*, the vertical fibres, the longitudinal fibres filling the intervals having been removed. Magnified 30 diameters.

the discs of longitudinal fibres cut across; the number of fibres in them may be counted, from two or three to thirty or forty: those nearest the surface are certainly the smallest, and they do not completely fill the meshes of the muscular network through which they pass (*fig.* 751.), but a certain quantity of fibrous tissue dips down among them: this, however, only for a little way. The *shape* of the longitudinal bundles is as various as their size— circular, polygonal, triangular, elliptical, in fact, every conceivable shape (*fig.* 751.); they seem moulded by the fibres among which they lie, or, more correctly, they and the others among which they lie, mutually regulate each other's shape and direction.

The peculiarity, then, of the arrangement of the intrinsic muscles of the tongue is this:— that there are three sets of fibres passing through the same area, and acting in three different directions; that these three directions are, in the main, at right angles the one to the other, in fact, that they coincide with the three axes of the cube; that to facilitate this arrangement, a beautiful system of pack-

Fig. 751.



Cortical layer from upper surface. (*Magnified* 30 *diameters.*)

a, vertical fibres; *b*, topmost stratum of the horizontal; *c*, longitudinal, in section, occupying the interspaces between the vertical.

age is adopted, whereby each of these is enabled to pass in a straight line to its destination without being interfered with by the other two; whereby the individual bundles of each set are isolated from their fellows; whereby the whole of them are contained in the smallest possible compass; whereby they not only admit the passage of, but mutually support and conduct each other; whereby, in consequence of this, they are enabled to dispense with the support of cellular tissue, which accordingly we find absent; whereby, lastly, the tongue contains the greatest amount of muscular tissue possible for its bulk. This system of package consists of this — that the crossing of the fibres of any two sets forms a lattice work, or mesh, through which the third shall pass, and that the successive layers of the crossing fibres shall be so arranged that the areolæ shall form continuous channels for the transmission of the perforating ones. In whatever plane we look at the fibres, we find that this is the case — that two sets are crossing fibres and one set perforating — that two are seen in profile, one in section; but, as we vary the plane, so do we vary the appearance of the fibres, one set alone remaining the same and two interchanging. Thus, in a transverse vertical section the transverse and vertical fibres are seen in profile, and the longitudinal in section; in a longitudinal vertical section the vertical and longitudinal are in profile, and the transverse in section; while again, in the horizontal section, the transverse and longitudinal are seen in profile, and the vertical in section. So, no set can be called a perforating set or a crossing set, — they are all equally so.

Again, we see that the office of the longitudinal fibres requires that they should have that special superficial arrangement which is the only one left them by the necessary disposition of the other two. The chief office of the longitudinal fibres is to alter the direction of the tongue longitudinally, to twist it from side to side, or up and down; any thing but a superficial distribution would render them powerless for this act. For if the longitudinal fibres were placed in the centre, it is evident that they could only *shorten* the tongue; but, being arranged superficially, when a portion of them contracts, that side of the tongue on which the contracting ones are is shortened more than the rest; in other words, the tongue is turned towards that side; and it is only when the whole sheath of longitudinal fibres acts equally that the tongue is contracted directly backwards.

Having premised this general description, I shall now proceed to give a particular account of the microscopical appearances of successive sections made in the three principal planes — the transverse, the longitudinal, and the horizontal. I shall begin with the *transverse* as being the clearest and the most illustrative.

The first transverse vertical sections, made at the tip of the tongue, of course remove successive portions of the papillary structure: we next come to the cutis — the dense areolar tissue subtending the papillæ — and many sections are made before the appearance of any muscle; we have in fact to get through the thickness of the cutis. The first muscular fibres that make their appearance are the *transverse*, consisting of a single slender bundle of fibres in that direction, occupying nearly a middle plane between the upper and under surfaces, lying horizontally, collected into a single bundle in the centre, but breaking up at each end into smaller fasciculi, which diverge as they pass to their insertion into the cutis at the sides of the tongue, so as to gain a more extended attachment. The sections following this display an increasing quantity of this muscle, the diameter of the unbroken bundle in the centre being greater, and the fasciculi into which it divides at the sides more numerous; but as yet no other system of fibres has appeared. The next addition, as we proceed backwards, is that of vertical fibres, which are at first very few and scanty, and placed not in the centre, but in two sets, one on each side of the centre; they converge a little as they pass upwards, and are rather curved, presenting their concavity outwards. The succeeding sections show them increasing in numbers and spreading towards the centre, where they finally meet, and then the central part of the tongue is constituted in the same way as it is throughout the whole succeeding length of the organ, namely, by decussating vertical and transverse fibres; but as yet no longitudinal fibres have appeared, and they are not seen till after the transverse area of the tongue has been entirely occupied by the vertical and horizontal fibres as above described. They first appear at the inferior surface, then at the sublateral and lateral regions; next they are seen at the centre of the upper surface in a small definite cluster, from which they spread out, and so complete the circumference of the tongue.

We see from this that the fibres that occupy the extreme point of the tongue are the transverse; that the next met with are the vertical; and that the longitudinal do not extend so far forward as either of the other two. This is what might be expected. The chief muscular requisition at the extremity of the tongue is the power of pointing it: the shape of a tactile part is eminently subservient to its power of touch, because exact localisation, which is a most important element in touch (if it is not the very essence of it), depends on the smallness of the touching part. Now the extremity of the tongue, of its ordinary broad, flat shape when at rest, would be a very poor tactile instrument, and very far removed from a form that would capacitate it for the minute appreciation of distance and form. In what way, then, is the desired pointed shape of the tip of the tongue to be produced? Manifestly by transverse contraction, for it is by the spread of the tongue in this direction that it departs from the pointed form; and so we see the transverse fibres continued beyond either of the others, and occupying at the extreme tip the whole of the space assigned to the muscular structure. Furthermore, the longitudinal fibres are not necessary at the extreme point, either to flatten or shorten the tip, which is brought about by its own elasticity immediately on the cessation of the contraction of the transverse fibres, or to move it in any direction, which is done rather by the movements of the parts coming immediately next the tip than of the tip itself. Thus, both negatively and positively, we see a reason for the continuation of the transverse fibres further forwards than either of the other two sets.

The section last described completes what may be called the theoretical structure of the tongue (it is shown in *fig.* 748., in one half of its extent): the next change is one of infraction of that completeness of muscular structure, occasioned by the entrance of the genioglossi muscles on the inferior surface, whereby the continuity of the cortical layer is isolated, there being no discs in the space occupied by the immergence of these two muscles. The subsequent changes in the appearance of successive sections, are just such as might be expected from the description already given of such sections when viewed by the naked eye; therefore, for the sake of brevity, I shall not here advert to them.

A *longitudinal* vertical section, of course, displays a reversing of the position in which the discs and profile interlacement are respectively seen; the discs are here in the central part instead of in the cortical, being the transverse fibres cut across; the cortical layer is free from discs (except where, from the vertical and longitudinal fibres being oblique, they are obliquely cut), and is occupied by the longitudinal and vertical fibres, both seen in profile.

A *horizontal* section displays very much the same appearance as the last: the discs are in the central part, and there is an absence of them in the circumferential portion; but in this case the discs are of the vertical fibres, in the other they were of the transverse.

Superficial sections, or sections made obliquely, I shall not attempt to describe; by such means the appearances might be infinitely varied, but their description would merely tend to confusion.

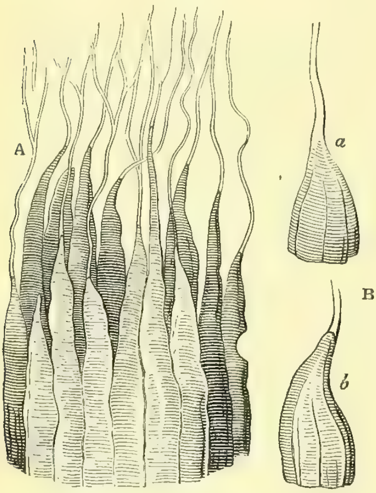
From the above account it is seen that the microscopical investigation of the subject not only confirms and proves the conclusion arrived at by other means, but adds many new and interesting facts, and supplies us with one more instance of that contrivance and adaptation of means to end that meets us at every point.

I have entered rather fully into the intrinsic muscular arrangements of the tongue, because there is no good account of the subject, that I can find, in the English language, nor of the appearances as seen by the microscope, in any language; and I considered such an account a desideratum.

Mode of termination of the intrinsic fibres. — All the intrinsic fibres of the tongue, and indeed, it may be said, almost if not quite all of the *extrinsic* too, terminate by becoming inserted into the cutis — the sub-mucous fibrous tissue — which is extremely dense and thick, particularly on the upper surface. The transverse and vertical fibres pass direct to the cutis; the longitudinal all ultimately have a similar insertion. In vertical sections the fibres may be seen passing up or down to the surface, and entering the cutis, which having pierced for a certain extent, they terminate:— some of them end just as they enter the fibrous tissue; some of them may be traced quite up to the papillæ.

It might naturally be expected that the muscular fibres of the tongue would, from their isolation, present great facilities for seeing the mode of the termination of muscle in fibrous tissue; and indeed this is the case in a remarkable degree; they seem to furnish the great desideratum of a natural isolation of the individual fibres, at the point where you are sure of seeing their union with the fibrous tissue that forms their means of attachment. As the opinions that I have come to from my own observations differ from those that are the result of some of the best researches on the subject that have been made, namely those of Mr. Bowman, as published in the "Philosophical Transactions," and in the "Physiological Anatomy" of himself and Dr. Todd, I would advance them with diffidence, and something like hesitation. The appearances that I have invariably seen, by daily examinations for some time, of sections from many tongues, is this: each fibre, before its termination, gradually tapers, in a fusiform manner, with more or less of acuteness; sometimes the tapering is rather sudden, in other cases very much prolonged (*fig.* 752. A); in all the tapering is con-

Fig. 752.



A. Fasciculus of the vertical fibres of the tongue, showing their fusiform extremities and the termination of each muscular fibre in a filament of white fibrous tissue. (Magnified 100 diameters. B. Magnified 200 diameters).

tinued so far that the muscular tissue becomes nearly as fine as the fibrous tissue in which it terminates: from this fine extremity the fibre passes off, and the appearances at the point of transition are of two sorts; the one as seen at B, *a*, where the muscle passes smoothly off in the fibrous tissue, and you cannot tell where the one commences and the other ends; the other as seen at B, *b*, where the pointed extremity of the muscle is a little rounded, and its outline plainly visible; but in this case, also, the diameter of the extremity of the muscle as nearly as possible coincides with that of the fibre. It is possible that the difference of appearance may depend in some degree upon difference of focus, but, certainly, I have not been able, in some cases, by any adjustment of focus, to get a clear definition of the point where the muscular structure terminated. In those cases where the outline of the termination of the muscle is defined, the transverse striation may be traced up to its very extremity; where the outline of the one merges in that of the other, the striæ seem also gradually to be lost, becoming a linear series of little dots, and so fading away (B, *a*). The conclusion that the appearance at once suggested to me was, that the sarcolemma, condensed by the diminution of its contents, passed off from the acuminated extremity as a tendon of white fibrous tissue; and this opinion was confirmed when I thought of the genesis of these structures. If, as seems probable from the account given by Schwann and other physiologists of the development of muscle, the sarcolemma is the persistent cell-wall of the original formation-cells of the fibre, and if white fibrous tissue is true zellenfasern — altered cell-wall of cells that have become elongated at their opposite nodes, and plicated as it were, — then we reduce the sarcolemma and the white fibrous tissue to the same category — altered cell-wall. The function of the cell-wall of the muscle-cell is to secrete that peculiar matter within it which ultimately becomes sarcous matter; the function of the cell-wall of the fibre-cell is to become elongated and plicated, or otherwise longitudinally striated. To explain, therefore, the gradual passage of one structure into the other, we have merely to suppose, on the part of the cell-wall, the gradual mergence of one function, and taking on of the other. These considerations at any rate tend to obviate any antecedent objections to the opinions suggested by the appearances, that would have arisen if there had been any thing essentially heterogeneous in the nature of the structures concerned. The fact, that Mr. Bowman's observations were made on the lower animals — fish, crustacea, and insects — may perhaps account for the difference of the appearances. It is a subject that requires more investigation, and no structures seem to me so much adapted for this purpose as the tongues of the lower vertebrata.

b. Extrinsic muscles of the tongue. — These are four in number, the *palatoglossus*, the *stylo-glossus*, the *hyoglossus*, and the *genioglossus;* attaching the tongue to the soft palate, base of the skull, hyoid bone, and lower jaw, and moving it nearly in the four cardinal directions, upwards, downwards, backwards, and forwards. They are all more or less of a mixed nature, being continued in some degree into the tongue. They move the organ *en masse*, and attach it to distant parts by virtue of their extrinsic portion; they contribute to the substance of the organ, and affect its form, by virtue of their intrinsic portion. It is this continuity of the substance of the tongue with its means of connection to distant parts that makes those connections so strong and safe; it is this prolongation of the extrinsic muscles into the tongue that renders the association of the extrinsic and intrinsic movements so intimate.

The *palatoglossus* (*glosso-staphylinus*), the smallest of these muscles, constitutes the connection between the soft palate and the sides of the tongue. At its origin in the soft palate its fibres are mingled with those of the palatopharyngeus; as it descends to the tongue it becomes much narrower, constituting the anterior pillar of the fauces; and arrived at the sides of the tongue, it again spreads out, and its fibres mingle with those of the styloglossus, some of them passing transversely into the medullary structure. It lies immediately beneath the mucous membrane, and in front of the tonsil. *Action:* To constrict the fauces (hence its name, *constrictor isthmi faucium*) by depressing the soft palate and raising the sides of the tongue.

The styloglossus. — A small slender muscle arising by a pointed tendinous origin from the inferior half of the styloid process of the temporal bone, and also slightly from the stylomaxillary ligament. It passes downwards and inwards to the base of the tongue, opposite to which it expands and becomes flattened; a few of its fibres bend inwards, the majority being continued longitudinally along the side of the tongue, where they may be traced to near the apex, contributing to the formation of the *lateral lingual* muscle. As they pass forward, they mingle with those fibres of the hyoglossus that have a similar direction, and with the inferior lingual. *Relations:* Externally, with the parotid and submaxillary glands, the external carotid artery, the facial artery, the Whartonian duct, the lingual branch of the fifth nerve, and the stylomaxillary ligament; internally, with the stylohyoid ligament, internal carotid, superior constrictor of the pharynx, the jugular vein, and hyoglossus muscle. *Action:* To retract the tongue, to raise and expand its base, and to render it concave from side to side by raising its borders.

The hyoglossus.— Flat, thin, and ascending nearly vertically, this muscle approaches a quadrilateral form; but, from the dorsum of the tongue ascending as it passes forwards, its anterior border is much larger than its posterior. It arises from the posterior extremity, and from the superior border and outer surface of the greater cornua of the os hyoides, and from the body in their immediate neighbourhood. From this double origin the fibres ascend in two distinct sets. Those from the greater cornua, passing up nearly parallel to one another, are inserted into the sides of the tongue; those from the body expand as they ascend, arch forwards, and, gaining the side of the tongue at a point superior and anterior to the other, pass forward along the border of the tongue, and unite with the styloglossus to form the lateral lingual. These two portions are separated below by a cellular interval; and above a few fibres of the styloglossus pass in between them. Albinus has described these as three distinct muscles: one, the *cerato-glossus*, arising from the greater cornua; another, the *basio-glossus*, from the body: and a third, intermediate, the *chondro-glossus*, taking its origin from the lesser cornua. *Relations:* The external relations of this muscle are, — from above downwards, with the submaxillary gland, the hypoglossal nerve, the mylohyoid, stylohyoid, and digastric muscles; internally, it covers the glosso-pharyngeal nerve, the middle constrictor of the pharynx, the lingual artery, the stylohyoid ligament, the geniohyoglossus, and, at its attachment to the tongue, the inferior lingualis, which separates it from the last mentioned. Bichat erroneously states that the lingual artery ordinarily passes between its two origins. *Action:* To depress the sides of the tongue and render its dorsum convex; to retract the tongue and draw it downwards. It is more frequently associated with other muscles than isolated in its action; and accordingly as it acts alone or together with other muscles, either as concurring with them or antagonising them, so its actions vary.

The *genioglossus*, the largest of all the muscles of the tongue, which it connects to the lower jaw, is of a radiated or fan-shape, and is placed vertically in immediate contact with its fellow of the opposite side. It arises from the superior genial tubercle of the lower jaw by a tendinous tuft from which the muscular fibres radiate to their different destinations. The most anterior, the shortest, forming the anterior free margin of the muscle, pass upwards and forwards to the tongue, having reached the under surface of which, they are continued, according to Cruveilhier, on that surface to the tip; but in all the specimens that I have examined they appeared to continue an oblique course to the dorsum. The succeeding fibres pass more and more backwards, and having reached the inferior surface of the tongue, are directed vertically to the dorsum, into the middle line of the whole of which they are inserted, from apex to base. The two muscles may be separated up to the point of their immergence into the tongue, but beyond that line their separation is no longer possible; for, having entered the tongue, they come into relation with the transverse intrinsic fibres, which they cut at right angles, and interlacing with which they pass to the cutis of the dorsum, forming part of the vertical intrinsic muscle, from the rest of which they are not to be distinguished except by their mesial situation. The fibres do not curve outwards, as supposed by Marjolin, to form part of the transverse lingual; nor do they expand at all at their insertion, as stated by Cruveilhier; there is no disposition to lateral divergence in any part of their course; on the contrary, their direction is rather upwards and inwards throughout, and their insertion extremely narrow — a mere line — as it might be imagined it would be, when its great longitudinal extent is remembered. The longitudinal furrow is, I think, mainly produced by the traction of this muscle in the median line. The most inferior fibres pass backwards and downwards, and are inserted into the hyoglossal ligament. Some of the fibres immediately above pass backwards, according to some authors, to the sides of the pharynx, where, uniting with the middle constrictor, they form the *genio-pharyngiens* of Winslow. *Relations:* Internally with its fellow, being separated merely by areolar tissue containing some fat, particularly at its inferior part and the *median fibrous lamina*, when the intermuscular areolar tissue is sufficiently dense to deserve that name; anteriorly, with the frænum, to which it is subjacent; inferiorly, with the geniohyoid; and externally, with the sublingual gland, the mylohyoid, hyoglossus, and inferior lingualis muscles, the ranine artery, and the gustatory nerve. The hypoglossal nerve threads its fibres, and passes forwards among them. *Action:* To raise and draw forwards the tongue; to assist in constricting the pharynx; to protrude, retract, or depress the tongue in the mouth, according as all or part of the fibres are employed; to depress the centre of the tongue, and render it concave, from side to side.

c. Accessory extrinsic muscles. — These are, in short, all the muscles that move the os hyoides without being attached to the tongue, for whatever moves the hyoid bone must move the tongue, which is fixed to it. They are accessory to the *proper* extrinsic muscles in two ways, either by acting in concert with them, or by facilitating their action on the tongue by rendering the hyoid bone a fixed point. Thus, in the first method, the stylohyoid and posterior belly of the digastricus concur with the styloglossus in drawing the tongue upwards and backwards. In the same way, the anterior belly of the digastricus, the mylohyoid, and geniohyoid, concur with the inferior portion of the genioglossus in raising and drawing forwards the hyoid bone, and facilitating the protrusion of the tongue from the mouth. By the second method the muscles from the styloid process to the hyoid bone assist the longitudinal intrinsic muscles of the tongue by rendering the base a fixed point from which they can advantageously act on its length, and in the same way the inferior set of hyoidean muscles are accessory to the hyoglossus by fixing the hyoid bone down. More might be said on this subject, but enough has been stated to indicate the important relation of these muscles to the proper muscles of the tongue, and for the sake of brevity that may suffice.

Movements of the tongue.—All the infinite variety of movements by which the tongue is, by virtue of its complex muscular organisation, susceptible, may be arranged under two heads,—its *extrinsic* and *intrinsic* movements; sometimes dissociated, more frequently concurrent: for the sake of clearness I shall consider them separately, and then group them.

First, the *intrinsic* movements of the tongue are of two sorts; those affecting its *length*, and those affecting its *direction*.

a. As affecting its *length*. The elongation of the tongue is provided for, like all intrinsic elongation, by diminution of calibre; in the tongue this is produced by transverse and vertical contraction, especially the transverse, whereby the tongue becomes at once elongated and pointed; by this means the tip of the tongue can be protruded beyond the teeth without any movement of the organ *en masse*, or any assistance of the extrinsic muscles. From this elongated state it is restored to its original position and shape by the contraction of all the longitudinal fibres composing the cortical portion, which draw it directly back, the transverse and vertical fibres at the same time ceasing to act. Thus we see that the central and cortical portions of the intrinsic muscles are antagonistic; but they are capable of association: for instance, when the tongue is to be flattened and its sides pressed against the teeth without any elongation, an action very frequent in mastication and in the pronunciation of some letters, this is done by the contraction of the vertical fibres associated with the longitudinal, the one diminishing the vertical thickness, and so spreading the tongue out, the other preventing the elongation which the diminution of vertical thickness would otherwise be attended with.

b. As affecting its *direction*. The direction of the tongue is entirely regulated, as far as the intrinsic muscles go, by the longitudinal fibres, and their power of modifying the direction of the tongue, as well as shortening it, depends on their power of partial action: thus the lateral lingual of one side can act, or of the other; the superior or the inferior, and the point of the tongue is of course moved to the side of the acting muscle. This modification of the *direction* of the tongue is, perhaps, the most complete movement that it possesses; it is certainly the most extensive: by it the tip of the tongue may be depressed deep below the incisor teeth, or reflected back on the soft palate, so as nearly to touch the uvula; or laterally, from the pillars of the fauces on one side it may be carried round the cheeks and alveolar arches to the same position on the other side: these are the cardinal points, up and down, right and left; they may be united in any proportions, so as to carry the extremity of the tongue to any intermediate position.

Moreover, the movements affecting the length of the tongue may concur with those affecting its direction; for instance, on applying the tip of the tongue to the root of a canine tooth of the upper jaw, on the outer surface of the alveolus, the tongue is elongated, and vertico-laterally flexed; on applying it to the last molar tooth of the lower jaw it is laterally flexed and shortened.

Secondly, the *extrinsic* movements of the tongue admit of the same division as the intrinsic, into those regulating its length, and those regulating its direction or shape.

a. Thus the tongue is carried upwards and backwards by the styloglossus, assisted by the other styloid muscles, downwards and backwards by the hyoglossus, directly backwards when these both concur; and it is carried forwards and protruded from the mouth by the genioglossus. These movements, *en masse*, almost always concur with the intrinsic movements, the whole organ following to a certain extent the direction of the extremity.

b. But the extrinsic muscles affect very materially the direction and shape of the tongue: the styloglossi raise and expand the sides, the palatoglossi raise and approximate them, and the hyoglossi depress them; the one set makes the dorsum of the tongue transversely concave, the other convex: moreover, the posterior fibres of the genioglossus draw the centre of the tongue forwards and downwards, so that they also render the tongue transversely concave. The action of the genioglossus is peculiar; the most posterior fibres draw forwards the base of the tongue, and are those chiefly concerned in the protrusion of the organ; the most anterior concur in replacing the tongue when thus protruded; when the whole muscle acts it compresses the tongue into a sort of button, and carries it deep down in the arch of the lower jaw. The relations of the hyoglossus and genioglossus are worthy of remark: they are congeners, inasmuch as they both tend to draw the tongue downwards; they are antagonists, inasmuch as the one tends to draw the tongue principally forwards, the other principally backwards; when all four muscles act, the tongue is depressed deep in the jaw, but further back than when the genioglossi act alone; when the two muscles of one side act, that side alone is depressed, and a certain torsion is given to the tongue which enables it to apply the tip advantageously to parts that it would otherwise be very difficult to reach. If the movement of the tongue in transferring the tip from the last inferior molar tooth of one side to that of the other be watched, with the mouth open, at a glass, it will be seen to be collected in a globe at the back of the mouth, and to rotate horizontally, as it were on a pivot. The only way in which I can conceive this movement to be brought about, is by the consentaneous action of the hyoglossus of the one side with the genioglossus of the other,—the one right with the other left, then the one left with the other right, and so on, the styloglossi and palatoglossi at the same time preventing the depression of the tongue.

But it would be vain to attempt to describe in words the endless variety of movements of which the tongue is susceptible; and if it were possible to give an idea of them, space could not be afforded: so, dismissing this part of my subject, I will proceed to the next.

3. *Tegumentary system.*—The tegumentary system of the tongue is formed by the mucous membrane of the mouth passing on to it from neighbouring parts, and undergoing special modifications according to the part that it invests. A superficial glance shows it at once to admit of a triple division, into, first, a really or apparently *plane* portion, situated in front of the epiglottis, beneath the borders, and on the free portion of the under surface; secondly, a *papillary* portion, covering the anterior two-thirds of the upper surface, the free borders, and the tip; and, thirdly, a *glandular* portion, occupying the posterior third of the upper surface, where it is folded into little crypts and raised in nodules over small mucous glands: these glands exist also along the sides and beneath the tip: they will be reserved for future description.

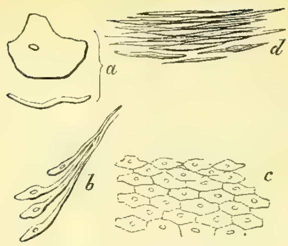
The mucous membrane here, as elsewhere, consists of three portions,—a basement or limitary membrane, underlaid by a submucous areolar tissue, and surmounted by an epithelium.

a. Cutis.—The sub-basement areolar tissue of the tongue exists in sufficient quantity and density to deserve the name of a true chorion or cutis. It is thickest at the upper surface, where it underlays the papillæ, especially towards the median line; its density too is the greatest here, sometimes amounting to almost a cartilaginous hardness, and the proportion of white fibrous tissue to the yellow is the greatest; it is thinnest on the under surface and edges, where it contains more of the elastic element, especially in the neighbourhood of the epiglottis; at the line where the attached and free portions of the tongue meet, it gradually merges off into the loose elastic web that underlays the mucous surface in these situations. Its inner surface receives the insertion of all the intrinsic muscles of the tongue, among which for a short distance it dips, and it sends processes into the folds that attach the tongue to neighbouring parts, as the glosso-epiglottidean and frænum. It is the medium in which the nerves and vessels destined to the surface break up previous to their ultimate distribution: the vascular ramifications form a plane network, coincident with the surface, from which, at regular intervals, the papillary vessels ascend.

b. The basement membrane is variously modified in the three situations above indicated; it is either continued plane, projected into papillæ, or folded into mucous crypts, from which its further involution constitutes the minute ducts and ultimate follicles of the mucous glands opening into these crypts: its description will be involved in the particular consideration of these structures.

c. Epithelium.—This very nearly approaches in character the cuticle of the skin, which it resembles in being of the scaly variety, in the amount to which it exists, and in its being divisible into two layers, a deep one closely adherent to the basement membrane, consisting of more recent cells, retaining much of the cellular form (*fig.* 753., *c.*), and a superficial one, readily desquamating, the cells of which are older and flattened into scales (*fig.* 753., *d.*). It exists in very different quantity in different parts, being most abundant where it invests the papillary structures. The shape of the individual cells is very various; where they are flattened their area is much extended (*fig.* 753., *a.*), and they look four or five times as large as the deep-seated ones; but probably there is no increase in size, their lateral extension resulting from their greater thinness: viewed in profile they appear quite filamentary; some of them are not flattened but elongated, so that they appear linear in all aspects, and are really so. In spite of all these modifications

Fig. 753.



Epithelium of the tongue.

a, a single flattened superficial cell, viewed superficially and edgewise; *b*, from the horse, showing the filamentary prolongation of a part only of each cell; *d*, superficial; *c*, deep layer.

a small single circular nucleus may generally be seen very plainly occupying a central position in the cell, and unchanged in form and size by any of the changes that the cell undergoes. Certainly the epithelium, covering most parts of the tongue, does not contain any pigment; but I think that covering the filiform papillæ in the centre of the dorsum very frequently does; and for these reasons,—because, first, the growth of the epithelium here is very abundant, and it seems a general rule that pigment should be associated with an abundantly nourished or rapidly developed epidermis, as is seen in hair, in the colour of those spots that are called moles, and the hair that proceeds from them, which, instead of being invisible, as in neighbouring parts, is dark and rank, and in the change of colour which the cuticle and hair covering the parts of generation undergo at the increase of the nutrition of the parts that accompanies the accession of the generative function; secondly, because we see that the epithelium does undergo great changes of colour, being generally darkest when most abundant; thirdly, because, in two cases that I have seen, in which the only diseased condition was an enormous development of the filiform processes which the epithelium forms in the centre of the tongue, the colour of the fur was a dark sepia or Vandyke brown, almost black, exactly that of pigment in other situations: we see too, when the epithelium has been rendered opaque by soaking the tongue in alcohol, that all the other papillæ are whiter than the filiform occupying the centre of the dorsum, which retain their tawny colour. The epithelium of the tongue differs from the dermic cuticle chiefly in its moisture, and the delicacy and softness of its structure.

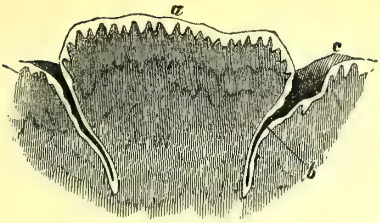
Papillary structure of the tongue.— The papillæ of the tongue are generally contrasted with those of the skin, in that while the latter are covered over with an even layer of epidermis, and therefore not visible to the naked eye, the latter stand out free from the surface of the epithelium, dipping down between them. But viewed by the light of recent researches, this is seen to be only the apparent difference, the real difference being that while the papillæ of the skin are sessile, the papillæ of the tongue are arranged in groups on proper pedicles or supports, whose tops and sides they cover, and which elevate them above the general surface. For it has been recently shown by Professors Todd and Bowman *, that the papillæ, heretofore considered simple, are really compound organs, and that they are covered by other smaller papillæ, whose form and whose method of nervous and vascular supply, show their true analogy to the papillæ of the skin. In physiological exactness, and to carry out the analogy instituted by these anatomists, we may say that these large papillæ, so called, are no more true papillæ, than the long processes in the intestine of the rhinoceros are true villi. Now, these secondary, or true physiological papillæ, are covered in by an even layer of epithelium, in just the same way as the papillæ of the skin; hence we see that the distinction generally laid down ceases. It would, however, be too great an innovation to reject the name of papillæ for those organs that have so long possessed it, and as the value and office of their different parts will be implied in their description, no misconception can arise. I shall, therefore, continue the old nomenclature.

There are three principal forms under which the papillæ, visible to the naked eye, exist on the surface of the tongue. 1st. The *circumvallate* (caliciform, Cuv.), the largest and fewest in number, and the most conspicuous, situated at the junction of the middle and posterior third of the tongue, where, by their arrangement in two lines, having a direction backwards and inwards, which meet in the centre, they form a V-shaped ridge, with the base directed forwards; 2nd. The *fungiform*, more numerous than the last mentioned, and smaller, irregularly scattered over the centre, sides, and apex of the tongue; and, 3rd, The *conical* or *filiform*, by far the most numerous and smallest, arranged in a dense pile over the whole anterior two-thirds of the upper surface, among which the last-mentioned are implanted. To these may be added a fourth class of simple sessile papillæ, first pointed out by Professors Todd and Bowman as existing on the apparently non-papillary surface immediately behind the circumvallate papillæ, and which I have found also to exist on the whole of the under surface of the free portion of the tongue.

The *circumvallate* papillæ are of the most complex form, and may be considered as consisting of two parts — a central, button-like projection, flattened or truncated at its free surface, and a raised border surrounding it in the form of a ring, of nearly equal elevation with the central part, the two portions being separated by a circumvallation, or fossa (*b*). When a vertical section is made of one of these papillæ (*fig.* 754.), the central portion is seen to be in the form of an inverted cone, and the surrounding fold is seen to constitute a cup, at the bottom of which the apex of the

* Physiological Anatomy, vol. i. p. 435.

Fig. 754.

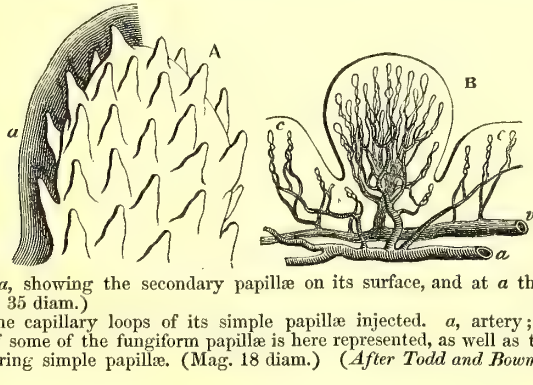


Circumvallate papilla seen in vertical section.
a, Truncated surface, or base of the cone; *b*, circumvallation; *c*, raised border. (Mag. 16 diam.)

cone is attached. At the attached portion the nerves and vessels enter, and the free truncated surface, or base, of the cone is covered with small secondary papillæ, concealed by the epithelium (*fig.* 754. *a*); the free border is also surmounted by secondary papillæ, so that it is, in fact, a circular compound papilla (*c*). The circumvallate papillæ possess the utmost irregularity as to size, number, shape, and arrangement. Their number has been much overstated by some anatomists; Cruveilhier gives it as from sixteen to twenty, Marjolin from nine to fifteen, Sœmmering from twelve to fourteen, and Meckel from three to twenty. I think the number given by Messrs. Todd and Bowman, as from eight to ten, is much nearer the truth; certainly, if ten can be counted, they must be considered well developed; frequently the number is below this — I have seen as few as five, or even four. In size they vary from that of an ordinary fungiform papilla to upwards of $\frac{1}{6}$th of an inch in diameter. They always assume more or less of the V-shaped arrangement, but the perfection with which the linear series is maintained, the straightness of the lines that form the angle, and the size of the angle so formed, all vary very much; I have seen them stretching across from side to side of the tongue, almost in a straight line, with a third arm projecting back from the centre, something like the form of a tripod; it is not uncommon to find a stray one or two scattered to a great distance beyond the prescribed line; the central one is frequently thrown back half an inch, and sometimes a lateral one is found quite at the edge of the tongue. In shape, the varieties are chiefly owing to the relative size and development of the central tubercle and the circular ridge surrounding it. Sometimes one of these parts is suppressed, and then you either get what appears to be a large fungiform papilla, or a set of ridges having something of a circular or quadrilateral arrangement, not to be distinguished from the fused rows of conical papillæ which surround the circumvallate on all sides, and which are, in fact, continuations and prolongations of their calices. Haller mentions having seen the circumvallate papillæ in two rows on each side; I have met with a similar arrangement on one side. This appearance may in some degree be accounted for by the supposition that the rows of conical papillæ, among which the large fungiform immediately in front of the circumvallate are planted, have attained a circular or calyx-like arrangement around them; for a large fungiform papillæ, situated in a calyx so formed, would produce a very perfect papilla circumvallata. This change is just the reverse of that which reduces a circumvallate papilla to a fungiform by the suppression of its surrounding ridge, and both, no doubt, are sources of irregularity. These papillæ are supplied by branches from the glosso-pharyngeal nerve, which may be distinctly traced to them; their vascular supply is abundant, and their epithelium thin and fine, so that during life, and when injected, they appear very red.

The *fungiform* papillæ, as their name indicates, have more or less of the form of a sphere supported on a pedicle; this is their typical form, but they often deviate from it; in size they vary from $\frac{1}{20}$th to $\frac{1}{50}$th of an inch. They are scattered over the sides and tip of the tongue, and on the dorsum in front of the circumvallate. They may be distinguished from the filiform, among which they are implanted, by their red colour, in which, in the thinness and smoothness of the epithelium investing them, and in the abundance of their vascular and nervous supply, they resemble those last described. When examined microscopically, they are seen to be covered on their sides and summit with secondary papillæ (*fig.* 755. A), to

Fig. 755.



A, *Fungiform papilla*, showing the secondary papillæ on its surface, and at *a* the epithelium covering them over. (Mag. 35 diam.)
B, Another, with the capillary loops of its simple papillæ injected. *a*, artery; *v*, vein. The groove around the base of some of the fungiform papillæ is here represented, as well as the capillary loops, *c c*, of some neighbouring simple papillæ. (Mag. 18 diam.) (*After Todd and Bowman.*)

which, in injected specimens, the individual loops of capillaries may be seen projecting with great regularity and beauty (B). The fungiform papillæ are largest about the centre of the tongue, smallest along the edges, and most numerous at the sides of the tip, but they are liable to the greatest variety in their size and distribution; I have seen them so large about the centre of the tongue, as almost to equal in size the circumvallate; I have seen them so numerous at the tip, as nearly to equal in number the filiform among which they were scattered; again, in the same region, I have seen them so scanty, that they could hardly be said to exist there.*

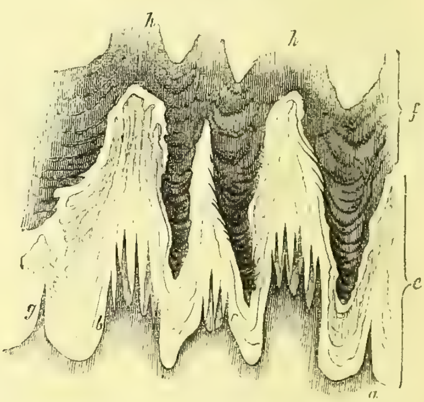
The *conical* or *filiform* papillæ, the third class, constitute the great mass of the papillary structure; they cover, in a close-set pile, the whole of the anterior two-thirds of the tongue, being limited behind by the circumvallate, and having the fungiform scattered among them: it is their structure that imparts the rough coriaceous character to the papillary surface, and they constitute the *fur* in the centre. They are altogether smaller, but in length they exceed, at least in the centre, the other two forms, and they exhibit greater diversity of structure and a more complete absence of typical shape than either of the other varieties. They affect in some situations a linear arrangement, principally at their confines, that is, in front of and around the caliciform papillæ, where they are continuous with the elevations that surround these papillæ, of which they are the continuations forwards and outwards, and along the whole free margin of the tongue, except at the tip, where the linear arrangement cannot be traced. In the first-mentioned situation their rows run forwards and outwards, coinciding with the arms of the V-shaped figure that the circumvallate papillæ assume; in the last-mentioned, they are placed vertically along the sides (*fig.* 745. *i i*): they have been well described and figured by Sœmmering.* Along the centre of the tongue, in the neighbourhood of the median furrow, the conical papillæ often assume a cracked and fissured appearance; but the linear arrangement is less marked here, and the fissures have no determinate direction, but can be made and effaced according to the movements of the tongue. The conical papillæ are largest in the neighbourhood of the circumvallate, where they are truncated, and where some of them assume almost a fungiform shape: they are longest about the centre of the tongue, near the median line, and smallest in the anterior part, near the side and tip. The form of the projections of basement membrane, on which the epithelium is

Fig. 756.

A filiform papilla taken from the dorsum of a tongue in which the fur *was much developed.* (*Mag.* 30 *diam.*)

a, imbricated scaly epithelium investing the cylindrical portion of the papilla; *b*, the commencement of its breaking up; *c*, its separation into its ultimate filamentary processes; *d*, the deep layer of epithelium exposed by the removal of the more scaly superficial one.

Fig. 757.



Vertical section of conical papillæ. (*Mag.* 25 *diam.*)

a, basement surface; *b*, conical papilla of ordinary shape; *c*, more nearly approaching the simple form; *g*, one quite simple; *e*, deep cellular layer of epithelium; *f*, superficial scaly portion; *h h*, points from which the filamentary prolongations would have passed up.

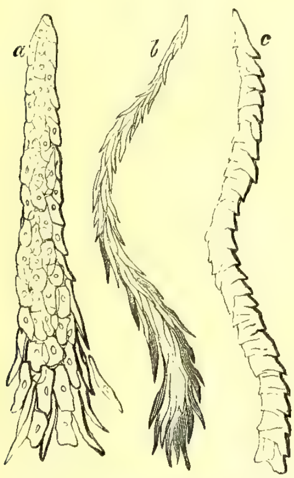
placed, constituting the mould of the true papillary structure, is generally something of a cylindrical shape, the top supporting secondary papillæ, or it is conical, the secondary papillæ being continued more or less down the sides: or the base is small, and supports a more expanded portion, and thus the conical is seen to pass into the fungiform shape. But it is in the epithelium that the characteristic difference between these and the other papillæ

* May not these varieties explain the corresponding diversities in the acuteness of the sense of taste, which we so often find in different individuals?

* Icones Organorum humanorum gustus et vocis. Francofurti, 1808.

is to be found. In the other forms we saw it continued over the whole compound organ as a thin indusium, covering in and concealing the secondary papillæ under its smooth investment, the scales being arranged parallel to the surface; but in the conical and filiform papillæ we not only see the epithelium existing in much greater quantity, but over each secondary papilla assuming a vertical arrangement, and, after continuing compact for some little distance, breaking up into a brush of hair-like processes (*fig*. 756.), the number coinciding with that of the secondary papillæ. Where the secondary papillæ are few the hairs are few, where they are many the hairs are many, and each hair may be traced down, by following the line in which the epithelium is vertical, to each papilla. In fact, these processes are true hairs, and only differ from other hairs in being short, uncompact, imperfectly elaborated, and in having the imbrication retroverse instead of directed forwards; and the secondary papillæ from which they spring are true hair papillæ, differing only from ordinary hair papillæ in being raised and grouped on a common pedicle instead of sunk in a proper follicle. In some cases the resemblance of these filaments to ordinary hair is very close indeed, as seen in *fig*. 758. ; indeed in *c*

Fig. 758.



Hair-like processes of filiform papillæ.
a, Mag. 150, *b* and *c*, 100 diameters.

the chief difference is in the direction of the imbrication : in some morbid specimens I have seen it even closer.

Now this difference in the arrangement of the epithelium on the different papillæ indicates, I think, a very important physiological distinction ; in one case we see the sentient papillæ covered by a thin layer of a fine epithelium, thinner over them than in the intervals between them ; in the other case we see each secondary papilla the seat of a rapid generation of epithelium that clothes the whole compound organ with a dense impenetrable brush of hairs : this latter arrangement seems as inconsistent with the possession of sensibility as the former seems adapted to it, and the difference would suggest to me the division of the papillæ into "*sentient*" and "*protective* ;" among the former I would class the circumvallate and the fungiform, among the latter the filiform and, with a certain qualification, the conical : but I shall return to this presently in speaking of the functions of these papillæ. The great difference between the filiform and conical forms is in the amount of the epithelium : in the filiform it is such as has just been described ; in the conical, the hairs are very short and thick, and terminate in an even plane almost as soon as they become separate, so that they have not at all a filamentary character. This epithelium is being constantly generated and as constantly thrown off, as is shown by the variation in the quantity of *fur* on the tongue from day to day. It is in these papillæ that the separation into two layers is best seen (*fig*. 757. *e f*), and the appearances of this separation are such as to make me think that the method of desquamation is not by the shedding of individual scales, but by the throwing off of the upper layer, the under layer taking its place, itself to become divided into a deep-seated and superficial portion, and to be in turn thrown off as it grows older. The vascular supply of these papillæ is very abundant, as might be expected from the rapid nutrition that is taking place from their surface. The pigmentary character of the epithelium, at least under some circumstances, has been already referred to.

The *simple* papillæ are scattered beneath the apparently non-papillary surface behind the circumvallate, beneath the edges of the tongue, and on the under surface of its free portion, also among the conical and filiform ; in the former situation they resemble the secondary papillæ of the circumvallate and fungiform, in the epithelium being continued smoothly over them ; in the latter, those of the filiform, each being the base of a hair-like process. The situation of these papillæ, their number and arrangement, is very well shown by injection, when the individual loops of capillaries may be seen passing up from the sub-mucous plexus at regular intervals, one to each papilla. The method in which the conical papillæ of the upper surface pass into the simple of the under, is this : — the ridges on the side of the tongue, to which reference has already been made, consist of fused conical papillæ arranged in linear series vertical to the edge, and, like them, crowned with secondary papillæ ; as they pass down the edge towards the under surface they become shallower, so that by the time they have reached that surface, the secondary papillæ, instead of being elevated, are sessile, and immediately subtended by the cutis. This is the true nature of those vertical ridges on the edge of the tongue described by Bichat, Sœmmering, and many other anatomists.

Structure of papillæ.— The nature of the true papillary structure, *i. e*. the contents of the projection of basement membrane, seems to be partly fibrous, partly granular: certainly something like yellow fibrous tissue can be detected, particularly on the addition of acetic acid; but those specimens that I have examined have appeared to be more granular than fibrous, and in some cases, where there has been a fortuitous rupture of the papilla, there has been an abundant escape of a finely granular material: the exact nature of this granular material I have not been able to ascertain; it is not fatty. The method of termination of vessels is sufficiently conspicuous, and has been already indicated. With regard to the termination of nerves I must confess, that, after long-continued and careful search, I have been unable to find any thing I can construe into a looped termination. I have traced the nerve for some little way into the simple papilla, and then, its outline becoming less and less definite, it has ceased to be visible, apparently from the loss of the strong refraction of the *white substance of Schwann*. If I might hazard an opinion, I should say that the axis was probably denuded of this investment, and, thus laid bare, underwent some specific peripheral modification. In a paper by Dr. Waller, recently published in the "Philosophical Transactions of the Royal Society," a method of nervous termination by *open mouths* is suggested: considering the solid nature of the nerve-axis, this appears to be an opinion that requires either some modification, or the confirmation of repeated and varied observations, before it can be received as certain. At present our means of examining the termination of nerves, either in the organs of sense or elsewhere, are imperfect, and until they are less so we can hope to make but little advance in this, at present, obscure subject.

Functions of the different papillæ.—Three offices are to be discharged by the papillæ — they are to exercise the sense of taste, the sense of touch, and to form a suitable clothing and protection to the tongue. The structure of the circumvallate and fungiform papillæ, their shape, their position, the nature of their epithelium, all point them out as the organs that are to discharge the first-mentioned function, and their nervous supply, which may be demonstrated with facility, makes that probability a certainty. To detail the evidence on which this conclusion is based would merely be to repeat what the reader will find given at length under the articles FIFTH NERVE, EIGHTH NERVE, and TASTE, to which I therefore refer him. By what papillæ, then, is the sense of touch exercised? I think by the conical, and by *them* in contradistinction to their non-gustatory congeners, the *filiform*. My reasons are, first, that the sense of touch is only possessed in any perfection by the papillæ at the tip of the tongue.* Now these are conical and of the form the most removed from the filiform type, that is, their epithelium is the least abundant of all the non-gustatory papillæ. Secondly, because the structure of the filiform papillæ is the most incompatible that could be devised for the possession of a sense of touch in any perfection. And, thirdly, because we *do* find, in fact, that the centre of the dorsum of the tongue, where the filiform papillæ exist in the greatest abundance, is the least sensitive part of any. Therefore, unless we assign the sense of touch to the gustatory papillæ, which the lowness of its condition at the back of the tongue, where the gustatory papillæ are so abundantly developed, seems to negative, we are driven to the conical as the only ones that can possess it. The filiform papillæ remain for the third office — that of clothing and protecting the exposed dorsum of the tongue; their pilose investment admirably adapts them for this, and at the same time it imparts to the surface a certain prehensile power, enabling it to take hold of and move readily what is placed on it, while the backward direction of the hairs adds yet more a special facility for transmitting food towards the pharynx.

Mucous glands.—These are largest and most abundant at the base of the tongue, where they occupy the space behind the circumvallate papillæ, and lie immediately beneath the surface, which they raise in nodular eminences. The most anterior of them form a V-shaped ridge, the counterpart of that formed by the circumvallate papillæ, from which they are separated by a corresponding furrow. These structures, which are true mucous glands, analogous to the buccal and labial, are of an oval or roundish lenticular shape: in front of the epiglottis they are gradually lost. Each gland is surmounted by a distinct orifice, most conspicuous in the most posterior of them, opening into a little crypt, generally closed and collapsed, but dilatable so as to be large enough to contain a mustard-seed, and into the bottom of these crypts the minute ducts of the glands open. Some of these crypts I have found extending into long and capacious canals, branching in different directions, and undermining the surface. I have traced some of them half or three-quarters of an inch before they have terminated in their blind extremities: their surface is quite smooth, and the orifices of the ducts of neighbouring glands might be seen terminating in different parts of it. They probably act as reservoirs, and permit some accumulation of the secretion, and also prevent the orifices of the glands from infarction by the matters passing over the surface. Similar glands, but smaller, are seen along the sides of the tongue, particularly near the base; and under the tip a small aggregation of them,

* There can be no doubt about this fact; and it is what we might antecedently expect, because it is the most movable part, and therefore has the widest range of application; because it is the most capable of movement, and therefore the best adapted for that which is an essential condition of touch; because we find it is the tip that we *do* apply to parts that we want to feel; because the tip is capable of receiving a pointed form, and therefore localising the impression more perfectly; and because the tip receives the most abundant supply of twigs from the fifth nerve.

first described by Nuck, may generally be detected: they are about eight or ten in number, much smaller than those at the base, situated on each side of the median furrow, and each surmounted by a little orifice. The true glandular nature of all these structures is proved by microscopical examination: they are seen to be true conglomerate glands, their ultimate follicles filled with an abundant secreting epithelium.

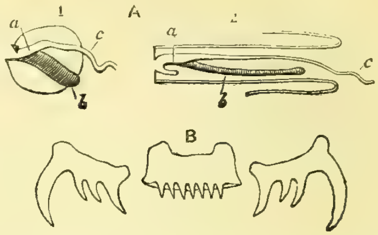
Vessels of the tongue. — The vascular supply of this organ, which is large in proportion to its size, is derived mainly from its proper artery, the *lingual*, but it receives some small branches at its sides and base from the inferior pharyngeal and palatine. The lingual artery arises from the external carotid, between the inferior thyroid and the facial: it passes upwards and inwards, at first superficial, covered only by the integument and fasciæ, to reach the posterior border of the hyoglossus muscle, beneath which it passes to its anterior border, where it breaks up into its terminal branches, the *sublingual* and the *ranine.* In the first part of its course it lies on the middle constrictor of the pharynx; in the second part it is covered by the hyoglossus and mylohyoid muscles, and lies on the middle constrictor and genioglossus. Previous to passing beneath the posterior border of the hyoglossus the artery is crossed by the hypoglossal nerve, which, at first placed below it, now rises above it; the hyoglossus muscle then separates the two, the nerve lying outside of it and the artery beneath it, but at its anterior border they are again in relation; the nerve, however, is now inferior, having crossed the course of the artery while beneath the hyoglossus. Its branches are, 1st, a *hyoid* branch, passing along the upper margin of the hyoid bone, corresponding to a branch of the superior thyroid running along the under margin of the bone, with which and with its fellow of the opposite side it anastomoses; 2dly, the *dorsalis linguæ* branch, ascending from the artery in the second part of its course, supplying the side and dorsum of the tongue; 3dly, the *sublingual*, one of its two terminal branches, passing downwards and outwards from the anterior margin of the hyoglossus to be distributed to the sublingual gland, cellular tissue, and mucous membrane adjacent; 4thly, the *ranine*, which may be regarded as its continuation, passing upwards and inwards in immediate relation with the genioglossus to the tip, where it anastomoses with its fellow. That the communication of the arteries of the opposite sides of the tongue is not very free, is shown by the imperfect injection of one side when the injection is made into the carotid of the opposite side: it is free enough, however, to make the ligature of the artery of one side of little service in stopping hæmorrhage of that side, the supply from the other being sufficient to keep it up.

Nerves of the tongue. — The tongue is supplied with nerves from three sources, two sentient — the *lingual branch of the fifth*, and the *glosso-pharyngeal*, and one motor — the *ninth* or *hypoglossal nerve.* The *lingual* or *gustatory* nerve, one of the three great branches into which the sensory portion of the inferior maxillary division of the fifth breaks up after its emergence through the foramen ovale, passes down, at first between the external pterygoid muscle and the small muscles of the palate, then between the two pterygoids, then between the internal pterygoids and the jaw, finally escaping from between these two at the anterior border of the muscle; it then runs downwards and forwards, under the protection of the jaw, to the side of the tongue, crosses the mylohyoid attachment of the superior constrictor, then passes forwards beneath the sublingual gland and to the outer side of the ranine artery, to terminate at the tip of the tongue. The numerous small branches that are distributed to the conical and fungiform papillæ may be seen ascending from the nerve whilst beneath the tongue, passing upwards and forwards through the substance of the organ to the mucous surface. The other nerve of sensation, the *glosso-pharyngeal*, the smallest and most anterior division of the eighth pair, emerges from the skull through the *foramen lacerum jugulare* by a distinct fibrous canal; it then descends between the jugular vein and internal carotid, passing forwards, in front of that artery and beneath the styloid process and muscles arising from it, to the anterior border of the stylopharyngeus, between that muscle and the styloglossus; it then passes under the hyoglossus, beneath which and below the tonsil it divides into its branches for the supply of the gland and the tongue: its arch across the neck is below that of the lingual, and above the hypoglossal, but deeper seated than either. The branches to the tongue are distributed to the circumvallate papillæ, and the mucous surface behind them. The *ninth*, or *hypoglossal* nerve, the motor nerve of the tongue, after escaping from the skull through the anterior condyloid foramen, lies at first deep, between the internal jugular vein and carotid artery; coming forward between them it becomes superficial, and forms an arch across the neck below, and parallel to, the digastric muscle, hooks round the occipital artery, and passes beneath the mylohyoid muscle, but superficial to the hyoglossus, at the anterior border of which it pierces the fibres of the genioglossus, and divides into its branches for the supply of this and the other muscles of the tongue: its relations to the lingual artery have been mentioned. For a more detailed account of these nerves, of their relations, branches, and the experiments on the results of which the present amount of our knowledge as to their function is based, the reader is referred to the articles Fifth Nerve, Eighth Nerve, Ninth Nerve, and Taste.

Comparative Anatomy. — The first indication that we find of any thing that can be construed into a tongue is met with in the *Articulata*, and, among them, in *Insects.* Its claim to the name is a matter of doubt among naturalists*; but since a certain oral appendage, at least in some of the orders, has received by common consent the name of *lingua*, I shall briefly describe it. The mouth of insects is furnished with two lips — an upper lip, or labrum, and a lower lip or labium; besides four jaws — a mandible, or upper, and a maxilla, or lower jaw, on each side. The labium, or lower lip, is divisible into two parts — a mentum, or basal joint, and a more flexible piece moving on this, the ligula, or labium proper. On the inner surface of this labium is developed a small process having a certain resemblance to a tongue, situated in front of the œsophageal orifice, and generally anchylosed with the labium at the front and sides of that opening; in some cases, however, as in the *locusts* and *dragon-flies*, it is free. This process Cuvier considered merely as a part of the labium, and accordingly called it *labium;* Fabricius and Latreille gave it the name of *ligula*. In shape it is generally short, but in *bees* it is long; it is frequently simple, but in the *wasp* its apex is trifid, the same in *Melolontha stigma;* in *Canabus* it possesses three short teeth; in *Elaphras* it terminates in a single tooth or point. In substance it generally approaches to a cartilaginous consistence, but in the *Orthoptera* and *Libellulæ* it is much more fleshy: and in the predaceous beetles it is as hard and horny as the integument. In some cases it is immovable, in others projectile and retractile within the mouth; in some cases smooth, in others covered with hairs, as is the case in the common hive-bee; in *Melolontha stigma* the hairs are incurved In the hive-bee the upper part of the tongue is cartilaginous, and remarkable for a number of transverse rings: below the middle it consists of a membrane longitudinally folded in inaction, but capable of being inflated to a considerable size: this membranous bag receives the honey which the tongue, as it were, laps from the flowers, and conveys it to the pharynx.†

Mollusca.—Gasteropoda. In the acephalous mollusca there is, of course, no tongue. But the *Gasteropoda* are provided with a very singular apparatus, which, since it is usually called the tongue, cannot be allowed to pass observation here, though its right to such an appellation is somewhat questionable. Its form is subject to much variation, but it may be described generally as a thin membrane, long and narrow, the greater extent of which is rolled into a tube. This tubular part (*fig.* 759. A, *b*), occupies the posterior portion of the membrane, the end being closed, while its anterior extremity is open and in connection with the œsophagus; in front of the tubular part of the tongue is a continuation of the same membrane, which is here flat, and in many species also, as in the common whelk (*Buccinum undatum*), it is recurved (*fig.* 759. A, 2).

Fig. 759.



A. 1. Vertical section of head of *Limax maximus*, showing the relative position of the mouth, *a;* tongue, *b;* and œsophagus, *c*.

2. Retracted proboscis of *Buccinum undatum*. *a*, mouth; *b*, tongue; *c*, œsophagus.

B, single row of tongue-teeth of *B. undatum*.

This membrane is covered on its upper surface with transverse rows of minute teeth, or rather plates with tubercular or toothlike processes upon them. The number of rows is considerable, and very variable, the terrestrial species averaging, probably, about eighty, and the marine possessing often many more; the number of plates in each row is subject to still greater variation: the common whelk (*Buccinum undatum*) has but three (*fig.* 759. B), the large garden slug (*Limax maximus*) has 180. The shape of the plates in terrestrial gasteropoda is usually irregularly quadrangular, slightly longer than broad, while in some fluviatile and marine species they assume most complicated and elegant forms (*fig.* 759. B). The centre plate of the row is always symmetrical, and its denticular projections point in the direction of the closed end, *i. e.* backwards, and nearly horizontally. The plates on either side of this central plate usually assume in terrestrial gasteropods much the same form and direction, while some of the fluviatile and most of the marine species present such an endless variety of forms, that the most that can be said of them, generally, is that the dental processes point backwards. *Fig.* 759. B represents a row of the dentigerous tongue-plates of the *Buccinum undatum:* there are seen to be only three; the central one symmetrical, the lateral ones of very different form, individually non-symmetrical, but having an exact correspondence to one another. The tongue itself (*fig.* 759. A, 2) is attached, as before stated, to the œsophagus near its anterior extremity, and lies beneath it. In the *Helices* and *Limaces* it is enveloped in the muscular head of the gasteropod (*fig.* 759. A, 1), its posterior blind end being just visible at the back part of the head, some distance below the point where the œsophagus leaves that part and passes into the abdominal cavity. In the whelk tribe it lies beneath, and parallel to, the œsophagus, and is free, though surrounded by strong muscular bands, the general direction of which is also parallel to the tongue. It is in this tribe that the anterior end of the tongue is curved downward,

* Ce qu'on a nommé langue dans les coléoptères et les orthoptères, ou l'extremité membraneuse de la lèvre inférieure, en mérite à peine le nom. Cuv., Leçons d'Anat. Comp., t. iii. p. 347.

† Kirby and Spence, vol. iii. p. 453.

while its posterior extremity unlike terrestrial species, is furnished with a strong retractile muscle. In some other marine gasteropoda, as the limpet, a very small portion only of the tongue is included in the head, whilst the rest of it lies folded up in the abdominal cavity, between the intestines and the muscular foot, but perfectly free; and in some cases it is nearly twice as long as the entire length of the animal.

Of the uses of this curious apparatus it is difficult to speak with certainty. The short thick tube of the terrestrial gasteropods appears adapted for the trituration of food preparatory to its passing into the œsophagus: these species are furnished with a large, strong, horny plate, fixed in the mouth at the upper part of the head, and, consequently, the flat end of the tongue acts as an under jaw working against this horny plate. It is not easy, however, to imagine that the long narrow tube of the whelk tribe can be used in the same way for triturating food, though the envelope of strong muscles would favour that idea, while the consideration of the still longer and perfectly free tube of the limpet renders this use of the tongue among the marine gasteropoda still more improbable. It is well known that the *Buccinum undatum* and its allies use the flattened portion of the tongue as a file, with which they bore holes through the shells of other species and then feed upon them, and the muscular apparatus by which this is effected is an admirable piece of mechanism. It consists of a protractor muscle, over the anterior extremity of which the curved portion of the tongue is flexed, which, by its self-elongation, probably by intrinsic transverse contraction, projects this recurved portion of the tongue from the mouth, and keeps it there; when the tongue is thus protruded, the retractor muscle, already alluded to, attached to its posterior blind extremity, contracts rhythmically, and so pulls the recurved portion with a sawing motion over the extremity of the protractor muscle, which acts as a pulley for it: thus the teeth which cover the outer or free surface of this reflected portion are brought into the relation, with the objects on which they are to act, the most advantageous for filing them away. But this gives us no clue to the determination of the manner in which the tubular part of the tongue is employed, nor am I aware of any probable conjecture having been advanced upon the subject.

Professor Loven, of Stockholm, has proposed a system of classification of gasteropoda founded upon the forms of the tongue-plates and their arrangement; and it is probable that conchologists will find the suggestion a valuable one, not so much for the sole foundation of an arrangement as for a check upon classification on other bases.*

* For much of the above detail I am indebted to Mr. Thomson, of King's College, as well as for the specimens from which the drawings were made.

Cephalopoda. Hitherto, in the insects among the Articulata, and the gasteropods among the Mollusca, we have only seen in the tongue an instrument for facilitating, mediately or immediately, the prehension of food: in the Cephalopoda we have the first structural indication of the sense of taste, and apparently in a perfection consistent with the high organisation of the animal in other particulars. In both the *tetrabranchiate* and *dibranchiate* orders of cephalopods we meet with tongues of very similar structure, possessing in both an anterior and posterior soft papillose part, and an intermediate portion invested with a horny lamina, beset with rows of recurved spines. It is hardly possible to help seeing in this distribution of parts the strong analogy it presents to the mammalian tongue, in which the gustatory papillæ are situated near the tip and base, while the centre of the dorsum is occupied by a rough indusium, subserving the same double office as the spiny lamina of the cephalopod, protecting the organ and facilitating deglutition. In the *Nautilus* the tongue is supported by an oblong horny substance, probably analogous to the basis of the hyoid bone, free at its posterior extremity, but embraced anteriorly by two retrahent muscles which arise from the posterior margins of the lower mandible. The anterior free extremity of the tongue itself is divided into three soft, fleshy, papillar caruncles, of which the central or anterior one is the largest. Behind them the surface is invested with a thin horny plate, on which are set four longitudinal rows of recurved spines, twelve in each row, each spine being about two lines in length. Behind this the tongue is again soft and sensory, but the papillæ are coarser; a fleshy fold projects forward from each side of the fauces, likewise covered with papillæ. In the *dibranchiate* order the papillary structure is less perfectly developed, and the central horny lamina, instead of being in one plane, is bent at right angles into a vertical and horizontal portion, the incurved spines being set only on the vertical part. The rows of spines are seven throughout, but in the *Onychoteuthis*, as they descend towards the base of the plate, the outer rows merge in those next them towards the centre till there are only three rows. The method in which the cephalopods appropriate their food, by tearing off piecemeal, by means of their strong and sharp mandibles, portions of the prey they have seized and are holding in contact with their mouth, renders the possession of the sense of taste of high importance to them, as the immediate contact of their food prevents their testing its nature by the sense of sight: at the same time, the full enjoyment of this sense is permitted by the nature of their food, its partially comminuted condition, and their protracted method of taking it.

Vertebrata.—In the Invertebrata the definition of a tongue depends, with few exceptions, on little more than locality and function—the requisitions of a tongue and the possession of an organ of any sort that fulfils those requisitions, constitute its possession, or any oral process, to which no other name can be assigned, is called a tongue. But when we enter the Vertebrata we find an organ of characteristic structure, conforming to a general type, possessing many common characters, of a form whose varieties are not so great as to prevent its being the name of a particular shape, and always constituted of those three systems previously enumerated as essential to the tongue of Vertebrata. I shall first consider the comparative anatomy of the bony system of the tongue in all Vertebrata, and then briefly refer to some of the principal characters of the organ itself in the four classes into which that subkingdom is divided.

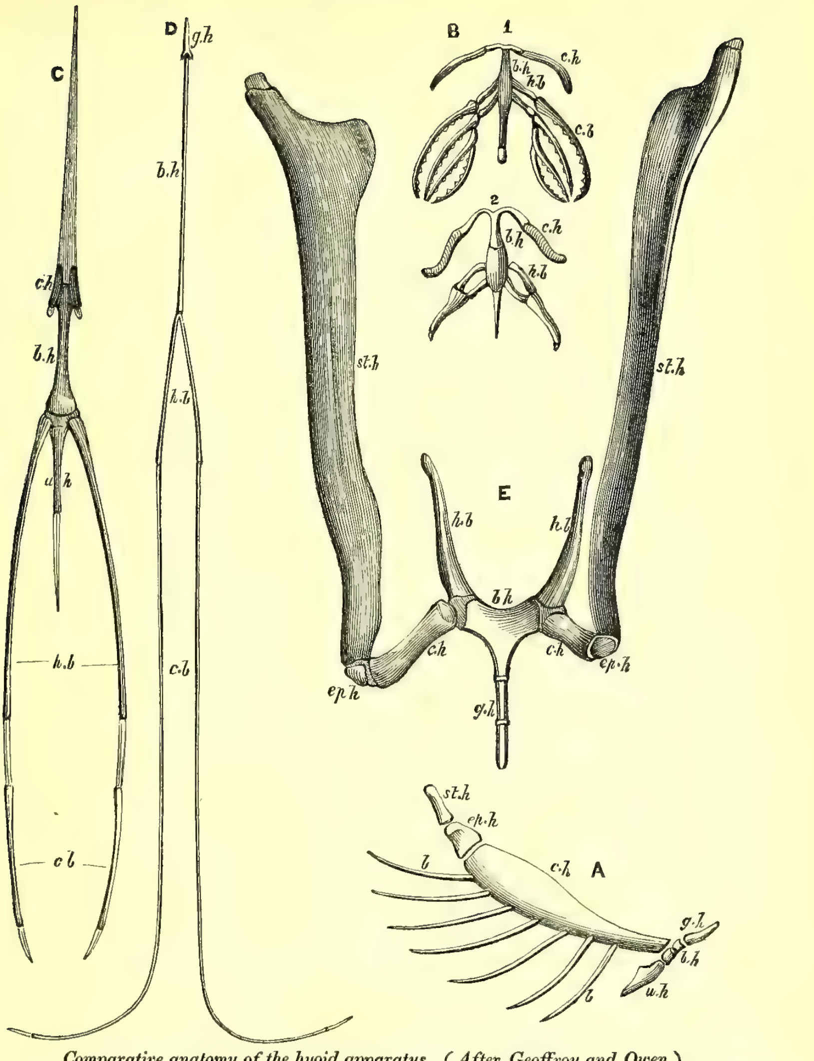
Hyoid apparatus. — The comparative anatomy of the hyoid apparatus is a subject of high interest, as it enables us, by its reflected light, to read successfully the true nature and value of the different elements of the structure as met with in man and other mammalia. It shows us, with the certainty of a demonstration, and the contrariety almost of a paradox, that the hyoid bone in man, which we are accustomed to look upon as a single bone whose dismemberment depends merely on late ossification, is, in reality, a composite structure — a contribution from two distinct systems of bones; that while the *body* and *lesser cornua* form part of the true *endoskeleton*, and are congeneric with the bony framework of the trunk and limbs, the *greater cornua* form part of the *visceral* or *splanchno-skeleton*, and are congeneric with the maxilliform supports of the teeth of the stomach of the lobster, or the bony pieces situated in the auriculo-ventricular ring, in the hearts of ruminants, or with other similar structures; and that, as we must look upon these in regard to the function they subserve, as respectively *digestive* and *circulatory* bones, so we must regard the greater cornua of the hyoid as *respiratory*.

To prove the truth of this proposition, it will be necessary to examine the state of the hyoid apparatus in water-breathing animals, and to connect its condition as found in these with what we find it in air-breathers, by tracing the modifications which its different parts undergo in those animals, part of whose existence is destined to the respiration of water, and part to that of air; we shall thus gain a clear insight into their homologies, and be able to refer part to part without the chance of fallacy, inasmuch as the link of their connection is lodged not in different individuals, but in different parts of the life of *one*. I shall describe it,

1st., in *fish*. Professor Owen has shown that the different segments of the true hyoid arch are so many elements of the inverted or hæmal arch of the third cranial vertebra. The centre of this arch in fishes (*fig.* 760. A) is formed by four small, subcubical bones, the *basi-hyals* (*b h*) (two only are represented in the figure, being seen in profile), from the sides of which extend upwards, backwards, and outwards, two long and stout cylindrical pieces, the *cerato-hyals* (*c h*); the summit of each of these is surmounted by a small triangular piece, the *epi-hyal* (*ep h*), and the arch thus constituted is suspended on each side, to the base of the skull, by a small, slender ossicle, the *stylo-hyal* (*st h*), which may be considered either as the entire proximal piece of the hyoid arch, or a dismemberment of that piece, according as the posterior division of the epitympanic, to which it is attached, is looked upon as the displaced proximal piece of the next arch in advance, the tympano-mandibular, or as itself the proximal element of the hyoid. This completes the hyoid arch: in most fishes, however, there are two more bones attached to the centre of the apparatus, one stiliform, projecting forwards, appended to the anterior surface of the median symphysis of the basi-hyals, the *glosso-hyal* (*g h*), the true lingual or tongue-bone; the other, the *uro-hyal* (*u h*), a vertically-expanded, triangular piece, extending backwards from the posterior surface of the basi-hyals. There are generally appended to the posterior and lateral surface of the cerato-hyals and epihyals a series of slender, slightly curved rays, varying in number from three to thirty, but generally about seven, as in the cod (*Gadus Morrhua*) (*fig.* 760. A); their office is to support the membrane that covers in the branchial chamber, whence they are called *branchiostegals* (*b*, *b*).

Immediately behind the hyoidean arch, we meet with a system of arches, the *branchial*, whose office is to support the gills, and whose structure, position, development, and connections prove them to have no relation with the true skeleton: they are generally five in number; the four anterior being *branchial*, the last, which is dentigerous and guards the gullet, *pharyngeal*. Each arch rises laterally from a median chain of ossicles attached to the basi-hyal, or uro-hyal when ossified, and consists of a short inferior piece, the *hypo-branchial*, surmounted by a long, curved piece, the *cerato-branchial*, bending first outwards and upwards, then forwards and inwards, under the base of the cranium. Now, these arches are what were just now stated to be homologous with the posterior or greater cornua of the hyoid apparatus, in all vertebrate forms, whenever they exist; that they are so, will best be shown by tracing the modifications they undergo in the metamorphoses of the anourous batrachians. *Fig.* 760. B, 1. represents the hyoid and branchial apparatus in the water-breathing tadpole; B, 2, where the same animal has become the air-breathing frog. In the full-gilled tadpole (B, 1), a simple *basi-hyal* (*b h*) supports laterally two *cerato-hyals* (*c h*), and posteriorly two short *hypo-branchials* (*h b*), to each of which are attached four cerato-branchials (*c b*). The second stage is marked by the divergence and growth of the extremities of the hypo-branchials and the progressive absorption of the cerato-branchials. At the third stage, the cerato-branchials have disappeared, and the hypo-branchials have assumed the character of true *greater hyoidean cornua* (B, 2, *h b*). In the fourth stage they

Fig. 760.



Comparative anatomy of the hyoid apparatus. (*After Geoffroy and Owen.*)
A, Fish (*Cod*). B, Reptile (*Frog*: 1, *tadpole*; 2, *adult*). C, D, Bird (C, *Crane*; D, *Woodpecker*).
E, Mammal (*Horse*).

became ossified, and, together with the cerato-hyal, coalesce with the basi-hyal. As in their previous condition they subserved to respiration, so now they do the same — as they before supported the branchiæ, so now they support the trachea and larynx: they may be always recognized by this relation, — they always embrace the commencement of the air-passages in their fork, being especially connected with the first segment of the cartilaginous framework of those passages, namely, the thyroid cartilage; the universality of this relation has induced Professor Owen to name them, in air-breathing vertebrata, *thyro-hyals* (*fig.* 760. C, D, E, *h b*, *c b*).

In *birds* (*fig.* 760. C and D), the elements of the true hyoid arch are either rudimentary or suppressed, while the *hypo-* and *cerato-branchials* (*h b*, *c b*) are enormously developed. The basi-hyal (*b h*) is generally elongated proportionately to the shape of the tongue, and to its anterior extremity is usually attached a glosso-hyal (*g h*), to its posterior a stiliform uro-hyal (*u h*) which is prolonged beneath the trachea. In C, which represents the hyoid apparatus of the crane (*Grus cinerea*), the glosso-hyal is seen to be wanting, and two rudimentary cerato-hyals (*c h*), *lesser cornua*, to be attached to the anterior extremity of the basi-hyal. In D is represented the hyoid apparatus of the woodpecker (*Picus*); the parts are seen to be very long and slender, furnishing the means for the lengthened protrusion of the tongue in pursuit of food. All the bones are seen to be linear; there is a long basi-hyal (*b h*), surmounted by an arrow-shaped glosso-hyal (*g h*), while two slender hypo-branchials (*h b*,) (*greater cornua*) are surmounted by two cerato-branchials (*c b*) of extreme length and tenuity, which, curving round the bird's occiput and vertex, are inserted by their cartilaginous extremities into a canal in the upper mandible, the orifice of which is placed to the inside of the right nostril; the true hyoid arch is here entirely suppressed. And, indeed, birds' tongues are not *attached*, they are *slung;* now, tongues are *attached* by the osseous or fibrous continuity of the hyoid arch; they are *slung* by the loose, unattached hypo- and cerato-branchials; and accordingly as either of these methods of connection with the body is most consistent with the tongue's functions, so the one or the other of these systems of bones preponderates.

In *mammalia* we find the hyoid apparatus recurring in its original completeness; the three pieces, the stylo-hyal, epi-hyal, and cerato-hyal, composing the lateral arms of the arch in the fish, have each their representative: the proportion of these parts, the completeness of their ossification, and their anchylosis, or separateness one from another, are liable to great variety, but either in the bony or ligamentous condition, fused or separate, the parts may be always traced. The cerato-hyals are represented by the lesser cornua; the stylo-hyals have their homologue in the styloid process of the temporal; and the epi-hyal, or intervening portion of bone, is a cylindrical ossicle connecting the two: these are seen in their greatest completeness in the true carnivora. In man the epi-hyal is not normally ossified, but remains in a permanently ligamentous condition, as the stylo-hyoid ligament. In some rare instances, this ligament has been ossified, and then the typical condition of the hyoid arch is restored; two or three of these instances have been recorded and figured by Geoffroy. In *fig.* 760. E is shown the condition of the hyoid apparatus in the horse; the stylo-hyals are seen to be very large, and approximate so nearly to the cerato-hyals, that the intervening bone, corresponding to the stylo-hyoid ligament in man, is seen to be a mere pisiform nodule (*ep h*); the hypo-branchials, or posterior cornua (*h b*), are of much the same shape as in man, while the basi-hyal projects forwards in a rostrum, to which is attached a glosso-hyal in two pieces (*g h*). In the ox the condition is much the same as in the horse, but the epi-hyals are longer, and the stylo-hyals shorter.

I will now briefly advert to the general characters of the tongue itself, as met with in the four classes of Vertebrata,—Pisces, Reptilia, Aves, and Mammalia.

Pisces. — The tongue in fish is very rudimentary; in some it cannot be said to exist at all; in others it is a thin, fleshy investment, that barely covers the glosso-hyal bone projecting into the mouth. In the *herring* (*Clupea Harengus*), it seems to be represented by a small muscle passing along the floor of the mouth to be inserted into the symphysis of the lower jaw, to depress and open which seems to be its function. In the *cod* it is round and thick, and seems to act as a sort of cushion. In the *conger* (*Muræna Conger*), in which it is very large, it seems to possess a hyo-glossus muscle, which, arising from the inferior portion of the hyoid arch, passes forward on either side of the tongue, which, by the action of one of these muscles, can thus have a lateral deflexion imparted to it. The structure of the investments of the tongue is not such as to imply the possession of taste in any degree, or any thing but a very low sensibility. In some species, as, for instance, in the sole (*Solea vulgaris*), the surface is regularly rugose, and might, at first sight, appear to be papillary, but no true papillæ are to be met with in any fish's tongue; their only representatives are the calcigerous processes, or teeth, with which the tongues of some species are more or less densely set, and which assist in prehension and deglutition. Whether the vascular, erectile tissue, situated on the palate of the *Cyprinoids*, has any connection with the sense of taste, is doubtful — probably not.

Reptilia. — The tongues of Reptilia possess a very wide diversity; some are immovable, others the most remarkable for their protractility that we find in any organism; some are long, some so short as to have been described as wanting; some are broad and thick, some slender; some present the development of papillæ in great perfection, some are quite smooth; the extremes of all these characters we find in the reptiles, and their opposite conditions in those the most closely allied. For example, among the *Saurians*, the tongue of the crocodile is so immovable, as to have been described by Aristotle as wanting; while the chameleon presents us with the most complete protractility of the organ that the animal kingdom furnishes. I think the teleologists have not a greater strong hold than that furnished them by the tongues of reptilia. Almost the only thing in common that can be assigned to them is this, that prehension is their principal function, and that the sense of taste is very subordinate.

a. *Batrachia.*—All the Batrachia, in their perfect state, feed on living prey*, and in many of them the arrangement of the tongue, to enable them to secure it, is remarkably curious. In the *frog*, which presents a good example, we see the tongue reversed, as it were, the base or attached end being in front, the apex or free extremity behind: its muscular constitution explains this arrangement. It consists essentially of two muscles, a genio-glossus and hyo-glossus, invested by the mucous membrane. The genio-glossus arises from the inferior maxillary symphysis, and, directed backwards towards the throat, spreads out, and, together with its fellow, constitutes the upper of the two muscular strata. The hyoglossi arise from the lower surface of the posterior hyoid cornua, are directed forwards

* In speaking of the frog Roesel says, "Prædam vix venatur eamdem potius præstolans, nec ullum unquam devorabit insectum motu destitutum." Hist. Ranar., p. 16.

under the flattened cartilaginous plate of the body of the hyoid bone, over the anterior border of which they are reflected as over a pulley, where, coming in contact with the under surface of the last-mentioned muscles, they curve backwards, radiate in a fan-like manner, and form the under of the two muscular layers. This is the position in a state of rest, the hyoglossus lying under the genioglossus, and the extremity of the tongue pointing down the throat in contact with the fauces, and forming a plug with which to close the posterior nares, and prevent the regress of air every time it is swallowed. But when the animal would seize its prey, the position of the tongue is suddenly reversed; the genioglossus contracts, and moving on its genial attachment as on a centre, the tongue is thrown forwards, the genioglossus now being below, the hyoglossus above. The apex of the tongue having come in contact with the prey to be seized, and secured it by its viscid secretion, the organ is instantly retracted and restored to its original position by the contraction of the hyoglossus. In many of the batrachians (as in the Triton) the tongue is fixed in its entire extent, and is of very various shapes, oblong, rhomboidal, heart-shaped, &c., affording generic and specific distinctions, of which zoologists have availed themselves in classification. The tongues of Batrachia are invariably soft, and, in some of them, as the frog, covered with well-developed papillæ, containing all the essential elements of organs of taste and touch; that they are the seat of an acute sense of taste is, however, highly improbable, not from any thing in their structure, but from the fact that these animals swallow their prey whole, without any subdivision, frequently alive, bolting it as soon as seized.

b. *Ophidia.*—In the ophidians the tongue is very much elongated, straight, flat or cylindrical, fleshy, highly protractile, and deeply cleft at the apex into two tapering points which are in a state of constant vibration when the tongue is protruded. These points are the extremities of two muscular cylinders, which form the substance of the tongue, and by their close apposition constitute that part of it that seems to be undivided: they may be traced a long way down in front of the trachea. When the mouth is opened the tongue very frequently cannot be seen, from its being drawn within a sheath which contains it, the orifice of which is placed in front of the aperture of the glottis. From this sheath, and from the mouth, it is being constantly projected, with a sort of vibratile darting movement, and, from a deficiency in the plates at the symphysis of the jaws, it can be protruded from the mouth without the jaws being separated: the character of this movement, and the pointed slender shape of the tongue, have given rise to the vulgar belief that it is the animal's weapon of offence, a sort of dart containing the poison that it instils into the wounds it inflicts. From the nature of the food of this order, from the disposition of the parts of the mouth, and from the short sojourn that the food makes in it, the perception of savours is probably very slight.

c. *Chelonia.*—In Chelonia the tongue is not elongable, and its muscular structure is very simple, consisting only of two pair of muscles, the genioglossus and hyoglossus. In the turtles the surface is smooth; in most of the tortoises it is clothed with very large and well-developed papillæ, long, soft, and flexible, arranged with great regularity in a close pile: the structure of these papillæ, together with the masticatory apparatus possessed by these animals, would imply their possession of a true sense of taste.

d. *Sauria.*—Among the saurians we find in the *Crocodile* a fixed tongue projecting so little from the floor of the mouth, that Aristotle, as has been stated, described it as wanting; it is covered with a coriaceous integument, and is remarkable chiefly for a valve-like process at its base, formed by a reduplication of the integument over the vertical ridge of the body of the hyoid bone, which, at the will of the animal, is capable of being applied to a similar one descending from the palate, and shutting off the mouth from the posterior nares and larynx, so that the animal can breathe when its mouth is under the water or engaged with its prey, and its nostrils only above the surface. In the *Lizard* we find a tongue, in shape very much like that of the *Ophidians.*

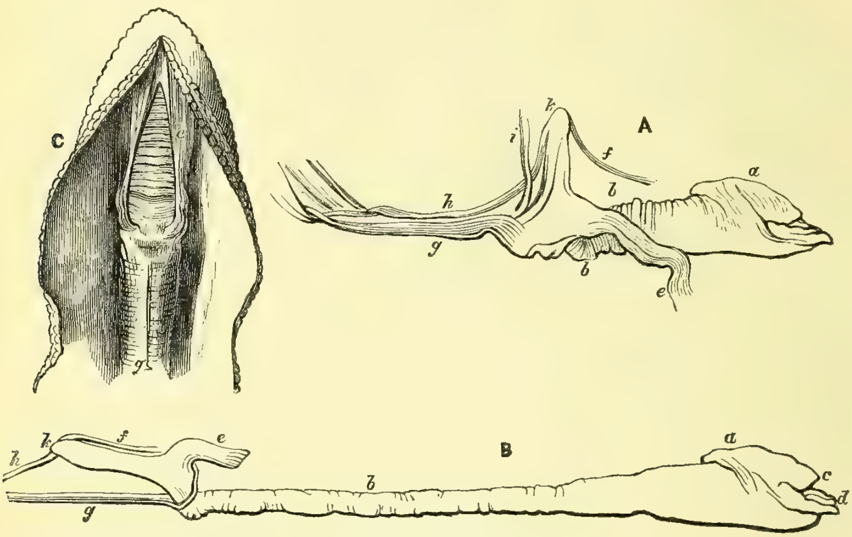
In the *Chameleon* we find an apparatus which, for its remarkable structure and powers, has always excited the attention and curiosity of zootomists: Perrault, Hunter, Cuvier, Vallisnieri, Vrolick, Houston, Milne Edwards, Spittal, Duvernoy, have all given their contributions to the subject; the connection of the mechanism with the resulting phenomena, as given by these authors, has been very diverse, and all, in the opinion of Bibron, unsatisfactory. "It is easy," says this author*, "to conceive and explain a part of these movements, by the structure of this tongue in the chameleons, because the hyoid bone and the muscles have been perfectly described, and because it is easy to isolate them by dissection; yet, by the very aid of this anatomy we perceive that the movements which this mechanism should effect would not suffice for the production of such an excessive elongation, that the animal, without using any violent exertion, can lance from its mouth, by a sort of expuition, a fleshy pipe of a length nearly equal to that of its whole trunk, and that it can retract it again within its throat with the same swiftness, and without one's perceiving any apparent movement in the rest of its body." The difficulty that Bibron felt was that of accounting for the very great *intrinsic* elongation of the tongue, and it appears to me to be a difficulty that exists; various authors account for it variously; in my own dissections I have not met clear evidence of anything that satisfactorily explains it to me. I shall first describe the tongue itself, and then the hyoidean appa-

* Erpétologie Générale, ou Histoire Naturelle complète des Reptiles, Paris, 1836, t. iii. p. 174.

mouth, it is seen to be a whitish, fleshy, ru-ratus and muscles, and from the description of the two deduce the most probable explanation of the movements.

When a portion of the integument and lower jaw on one side is removed, so as to expose the tongue when retracted within the gous mass, about an inch and a half long, filling the buccal cavity, so as to depress the floor of the mouth and throat, in shape something of a cone with the base in front: the posterior half, or smaller part, is seen to be thrown into deep and numerous transverse rugæ (*fig.* 761. A, *b*, and C.) which extend

Fig. 761.



Tongue of the Chameleon.

A, retracted. B, elongated. C, seen from beneath, *in situ*, by incision and separation of the integument.

quite up to the hyoid bone, and give to this part the appearance of an earth-worm, a simile suggested by Belon. When the tongue is drawn out it is seen to be capable of great extension (B), the extension taking place in the posterior or rugose portion, and being effected by the obliteration of the transverse rugæ, which one by one are smoothed or flattened out as the extension is continued, so that when it is stretched as far as it will go by moderate traction, the tongue, instead of being an inch and a half long, of which only half is occupied by the extensible portion, is five inches long, the extensible part occupying about six-sevenths of the entire extent, and being much attenuated (B, *b*), while the anterior portion retains its original size and shape (*a*). The tongue is thus seen to be composed of two parts, a club-shaped extremity and a highly extensible medium of connection between this extremity and the hyoid bone: these two parts I shall now describe.

The anterior club-shaped extremity is about three quarters of an inch long, and three lines in diameter, and in shape reminds one of the corolla of a *labiate* flower; in fact it is *bilabiate:* it has a sort of dome above (*a*), terminated in front by an upper lip (*c*), which is opposed by a more projecting lower lip (*d*), and between them is situated a funnel-shaped mouth, which, when closed, as in A, forms a horizontal cleft, but is capable of being opened as shown in B, (and to an extent greater than that represented in the figure,) and closed on any object at the will of the animal, so as to assist in the prehension of food. These lips are furnished with a sort of orbicularis, and, no doubt, too, with muscles that shall raise the upper and depress the lower; but I have been unable to detect any fibres going in such a direction as to produce these movements. This part, as well as the whole of the tongue, is invested with the mucous membrane of the mouth, and the upper surface of the dome and lower lip, are covered with minute papillæ, invested with a fine epithelium, and disposed, in the former situation, in rows, indicated by the lines (A, *a*). The part which covers in the infundibular cavity, and which, after the analogous part in a labiate flower, I have called the *dome*, Bibron has not ill compared to a tongue reversed.

The second portion consists essentially of a membranous tube, threaded, as it were, by the long cartilaginous stilet, or tongue bone, of the hyoid apparatus (*the glosso-hyal*). This cartilaginous stilet, which has been erroneously described as bony, is about an inch and a half long, and consequently passes through the entire length of the tongue when retracted, its anterior extremity being received into the lower lip of the club-shaped portion: it threads the tongue much in the same way as a bodkin threads a bag when furnishing it with a running string, and it is by the puckering of the membranous portion upon this basis that the transverse rugæ are formed. The membranous tube itself (which has been compared to a pipe, a piece of intestine, a worm, &c.) is very complex in its structure: it consists, first, of an investment of mucous membrane, very thin and extensible, covered, apparently, by a single layer of epithelium, and a good deal of bluish-grey pigment, and underlaid by fibrous tissue disposed at right angles, transversely and longitudinally. When the sheath, thus composed, is cut open, it is seen to contain another fibrous sheath, smooth, dense, white, and shining, the proper sheath of the stilet, which it closely invests, and which smoothly glides in it. Between these two sheaths is a cavity which is occupied, first, by a longitudinal muscle on each side (essentially a hyoglossus), a very fine and slender fascicle, which runs the entire length of the tongue, and retracts it when protruded; secondly, by a nerve on each side, disposed, when the tongue is retracted, in regular sinuosities, and, when drawn out, about five inches long; it does not appear to give off any branches to the muscle, and does not diminish in size as it advances, so that it is probably distributed to the extremity, and is sensitive; thirdly, by some cellular tissue loosely connecting the mucous investment with the fibrous sheath of the stilet; fourthly, no doubt, arteries and veins. The proper sheath of the stilet does not contain a canal, but is attached to the surface of the stilet, which glides in it not by its movement on the sheath, but by the movement of the parts of the sheath on itself. When the stilet is retracted it is seen to be cylindrical throughout, but as it advances its sheath accumulates on its anterior extremity, and it seems gradually to become club-shaped, so that when the tongue is completely retracted the under lip is filled not only with the extremity of the stilet, but with the sheath accumulated on it. Cuvier has described an annular muscle existing throughout the entire length of the membranous portion, which he describes as the proper muscle of the tongue, and to which he attributes its self-elongation. If such a muscle exists, which I will not positively deny, it would fulfil all the required conditions, and leave nothing to be explained; but I confess that, after careful microscopical research, I have been unable to find any muscular fibres having a transverse or circular disposition, all being referable to the longitudinal bundles already referred to. Hunter has described what he considered to be two coils of some firm substance, wound in opposite directions, which by their approximation would become straightened, and so lengthen the tongue; — this is an ingenious hypothesis, but no more: there is nothing that will bear such an interpretation. Perrault, in speaking of the lungs of chameleons*, expresses an opinion that the tongue is driven, or, as it were, coughed out by the sudden expulsion of the air which the lungs contain.

The hyoid apparatus consists of the horizontal projecting portion — the stilet already referred to, and four cornua, two short anterior ones, and two long vertical posterior ones (*fig.* 761. A and B). These parts can move freely on each other, the articulation between the stilet and the greater cornua is particularly free. These cornua ascend, and are suspended loosely behind the jaws; they are about three quarters of an inch long, and are clothed with the muscles that are attached to them. These muscles are, 1st, the *geniohyoid* (*e*. A B and *C*.), arising from the inner surface of the symphysis menti in contact with its fellow, and inserted into the inferior extremity of the vertical cornua, sending up a slip which is attached to its whole anterior border. 2dly, a distinct, small fasciculus, the *cerato-maxillary* (*f*), arising from the inner surface of the lower jaw, and inserted into the apex of the vertical cornua. 3dly, the *sternohyoid* (*g*), arising from the *inner surface* of the sternal extremity of the fourth and fifth rib, and inserted into the junction of the cornua and glossal portion of the hyoid. 4thly, the *cerato-sternal* (*h*), more slender and flattened than the last, the antagonist of the cerato-maxillary, arising from the outer surface of the sternal extremity of the second rib, and inserted, just opposite the cerato-maxillary, into the apex of the greater cornua. 5thly, the *omo-hyoid* (*i*), inserted with the sterno-hyoid. This complicated arrangement of muscles, which I have drawn from nature* in *fig*. 761. A, is the mechanism for the direction and extrinsic propulsion of the tongue; by it the lower extremities of the greater cornua are drawn forward, and the summits depressed, so that, instead of being vertical, they are horizontal and advanced (B). The advance of the whole tongue thus gained is nearly an inch, and since the muscles that principally effect it, the genio-hyoid (*e*), are very strong, and the movement quick and forcible, the question may arise — Is this projectile movement sufficient to send the rest of the tongue forward, and effect its elongation, after the hyoid apparatus has come to a stop, in the same manner as the arrow flies from the string of a bow, though the string itself is suddenly arrested? I think not. I think that some such muscular arrangement as that described by Cuvier must exist; and possibly, some transverse bundles of fibres of not very characteristic appearance, which, from the absence of transverse striæ, I rejected as muscle, might have been of a muscular nature. The retraction of the tongue is easily accounted for; it is simply drawn back on the stilet by the longitudinal muscles. The use of the stilet appears to be, partly as a support to the tongue when in a state of rest, and partly to direct its movements; for aim is seen to be taken while the tongue is still retracted: the animal first places itself in such a position that its head shall be turned directly to the object to be seized; it then fixes its head still more accurately, then slowly opens its mouth to a sufficient distance to allow the free egress of the tongue; it then seems to fix it with a sort of tremulous rigid

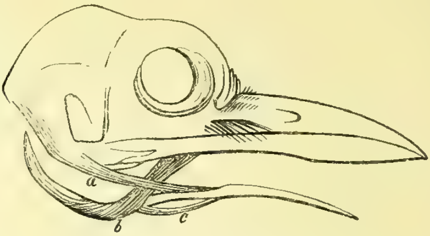
* Essais de Physique, t. iii

* It may be well to state that not only these, but all the figures illustrating this article (with one or two exceptions, which I have acknowledged), are original, and have been drawn by myself from nature, so that I can vouch for their correctness.

movement, and, in an instant, the tongue has been shot out, has again disappeared, and with it its prey has disappeared too, the whole being performed with a velocity that startles one afresh every time it is witnessed.

Aves.—The tongue of birds may be stated, in general, to be, like that of reptiles, prehensile and non-gustatory. Taste and mastication, or, at any rate, taste and some delay of the food in the mouth, always go together; in birds the food experiences no delay in the mouth, but, in almost all cases, is bolted at once. In most instances, true prehension, or the *seizing* of the food, is performed by the bill, in some few by the tongue; in nearly all, however, the securing of it when in the mouth is effected by the tongue, which is armed near the base with numerous spines, directed backwards (*fig.* 763. A B D), that prevent the regress of the prey, whether alive or dead, and which, with a similar structure at the roof of mouth and throat, must greatly assist the first stage of deglutition. The structure of the tongue of birds is generally such as not to admit of intrinsic elongation; its protrusion therefore can only be effected by the movement of the organ *en masse;* and this is produced to a surprising extent by a particular arrangement of the hyoid bone and its muscles, which I will now describe. The general character of the hyoid bone of birds, as already stated, is elongation—longitudinal extension, and to this add the fact of the suppression, entire or partial, of osseous or ligamentous attachment of the hyoid elements to the skull, such attachment being inconsistent with the required free movements of the organ. From the posterior part of the body of the hyoid bone project back the slender posterior cornua forming, by their divergence, an acute angle, embracing in its apex the upper part of the larynx: as they pass beneath the occiput they curve upwards, and are surmounted by slender pieces, frequently cartilaginous (*cerato-branchial*), having a still greater curvature; so that the whole greater cornua, as thus constituted, embrace the back of the skull, to the shape of which their curve is moulded, and on which they are made to glide backwards and forwards by the muscles that regulate the protrusion and retraction of the tongue. The principal of these muscles are two pair; the first the analogue of the *stylo hyoid,* which retracts the tongue, and the second pair which Cuvier has called the analogue of the *genio hyoid* — the *conical* muscle of Vicq d'Azyr,—which draws the tongue forwards: the obliquity and length of these muscles, and the free unattached suspension of the hyoid apparatus, render the movements of the tongue very free, and their range extensive. The *retrahent* muscle, the *stylo-hyoid* (*fig.* 762. *a.*), arises from the posterior part of the lower jaw, and passes forward to be inserted into the upper surface of the junction of the cornua and body of the hyoid: in some birds it is more voluminous than in the species figured, and has a more extended insertion; it retracts the tongue. The *protrusor* (*b.*), which Cuvier has named, with apparently insufficient reason, the analogue of the genio hyoid, arises from the inner

Fig. 762.

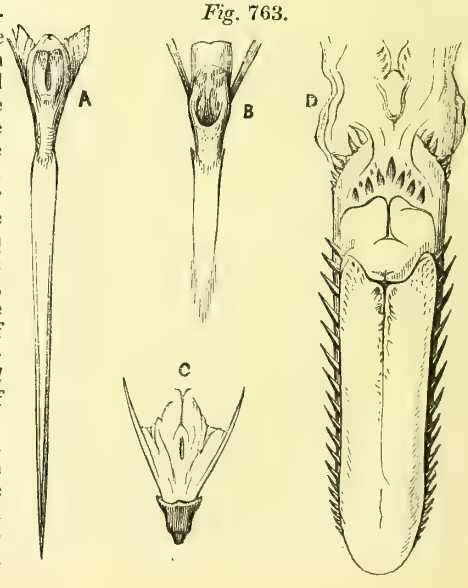


Muscles of the Tongue of the Fieldfare (Turdus pilaris). *a*, retractor; *b*, protrusor; *c*, cerato-glossal.

side of the lower mandible, passes downwards and a little backwards to the posterior cornua, which it embraces in its fibres from the point where it comes in contact with it to its extremity: the fibres become increasingly oblique as they pass back, and embrace the cornua in a muscular cone, which, by its contraction, causes the cornua to slide forwards in it, and so protrude the tongue. in the woodpecker, in which the hyoid cornua pass completely round the head and into the upper mandible, this muscle is of proportionate length. Besides these, there is a *mylo hyoid,* a thin layer passing from the lower mandible to a median fibrous line, and a *cerato-hyoid* passing from the posterior cornua to the uro-hyal, approximating these, and so directing the apex of the tongue to the opposite side. *Fig.* 762. *c.* is a small muscle, which I cannot find described; it passes from the under surface of the basi- or glosso-hyal to the greater cornua, into which it is inserted within the sheath of the conical muscle. I would suggest the name of *cerato glossal* for it; its action is to increase the curvature of the cornua, and thereby draw the tongue back.

Fig. 763. represents some different forms of

Fig. 763.



the tongue in birds. A, is that of, the snipe (*Scollopax gallinago*), which is seen to be linear; B, of the fieldfare (*Turdus pilaris*), the epithelium breaking up into a leash of filaments at its extremity; C, that of the king-fisher (*Alcedo ispida*), so short that it hardly projects from the surface at the bottom of its long bill; D, is the tongue of the common goose, furnished with a linear series of spines on each side, forming a serrate margin, which, with a corresponding serration in the upper mandible, constitutes a sort of sieve, through which the bird sifts and strains, as it were, the mud and water which it palpates in search of food. In the back part of the tongue, both in this and in the other figures, there is seen to be a peculiar armature of recurved spines, whose arrangement in the different species is constant and characteristic. Some good representations of different varieties of tongues are given in the article Aves.

Mammalia.—The tongue of mammals differs not in any material point from that of man. The proportion of the different parts of its muscular structure differ more or less widely from the human type, and we find certain muscles that have no place in the tongue of man: to enter into the minutiæ of these diversities would not, however, comport with the scope of the present article; they must be sought in monographs especially devoted to this part of the subject. The coincidence of the size and form of the tongue with that of the inferior maxillary arch is very general; in the *rodents* this is very conspicuous, the tongue being of the same wedge shape as their cuneiform jaw. In some animals, as in the ant-eater and giraffe, the tongue admits of great elongation, and becomes an important organ of prehension. The different elements of the tegumentary system are merely modifications of those found in man: the three orders of papillæ are generally sufficiently conspicuous, and in most instances they are more regularly arranged, and their structure is more typical than in the human subject; for instance, the circumvallate papillæ are symmetrical, they present a greater contrast to the rest in number, being fewer than in man, and none of the fungiform approach them in form; the shape of the fungiform too is not liable to any variety, and they are implanted with great regularity among the conical. The conical papillæ are generally true cones, and are arranged with mathematical precision in lines in different directions, accordingly as they are viewed. All these papillæ may be well seen in the dog. In the *felidæ* the conical papillæ of the centre of the dorsum are converted into recurved spines of great size and strength, which the animal uses in scraping the meat from the bones when feeding, and in combing its fur.

Functions of the Tongue.— The physiology of the tongue, like its organisation, is double, all its functions being referable either to those sensory or muscular endowments which it possesses in so remarkable a degree. Naturally, these are intimately associated, its sensibility being necessary for the direction of its muscular action, and its movements necessary for the perfection of its sensibility; a systematic consideration of them, however, necessitates their separation, and those functions that are referable to the tongue as an organ of sensibility, have already been treated of in the articles Taste and Touch, to which the reader is referred; it only remains for me to consider those that it possesses as an organ of motion.

These are *prehension*, *mastication*, *insalivation*, *deglutition*, *speech*, and one or two unimportant and non-essential offices in which it is engaged, which may be called the *accidents* of its physiology, as *despuition* or *spitting*, *whistling*, &c. Of these the four first-mentioned belong to the tongue as an organ of digestion; they are, in fact, the first four stages of that process; all four exist in all mammalia, the first and the last in all vertebrata; speech and the other non-digestive motor functions are peculiar to man.

Prehension. — The tongue is not, properly speaking, in man, an organ for the prehension of solid food, that office being performed by the hand, for which the opponent arrangement of thumb and fingers eminently fits it, so that the human tongue has not those additional qualifications which we find in other animals to adapt it for an organ of prehension. And this, I may remark, is an instance of a very general law—that the ascent in the animal scale is not a passage from animals with simple organs to animals with complex organs, but from simple individuals with organs of complex function, to complex individuals with organs of simple function, the addition as we ascend being, not of functions, but of parts to discharge those functions, and the advantage gained, not another thing done, but the same thing done better. Thus in man, instead of having one office more, the tongue has one office less than in many animals below him; and the delicate and extended prehension supplied by his hands, diminishes by one item the complexity of function, and, therefore, of organisation of his tongue. So that in judging of the elevation of animals by their individual organs, supposing such a method to be admissible, we must not look to complexity of structure of those organs, but to the perfection of the resulting function. But to return.

In the prehension of *liquids*, or *suction*, the tongue in man *is* engaged; constituting a movable wall of the oral cavity, it acts as a piston, and draws the liquid into the mouth by the formation of a temporary vacuum. Bichat enumerates three methods of the prehension of liquids, by suction, by drinking from a vessel, and by infusion into the throat; in the first two the tongue is concerned; in the last, which seems to me hardly to deserve the name of prehension, it is not. In *suction*, which is peculiar to the infant, the nipple is seized by the lips, which are compressed around it by the orbicularis oris; the velum palati is elevated so as to close the posterior nares; the tongue forms, by the contraction of the middle fibres of the genio-glossus, which depress its centre, a longitudinal channel, which receives the nipple, and transmits the milk to the pharynx as long as a vacuum continues to be formed. In drinking liquids from a vessel the tongue forms a channel for its transmission, but it flows down to the pharynx by its own proper gravity.

Mastication.—As far as relates to the tongue, which here, however, is only subsidiary to the teeth, the mechanism of mastication may be divided into three stages:—first, that of placing the food in an advantageous position with regard to the teeth; secondly, affecting the position of the food in a definite manner when under the action of the teeth; thirdly, collecting the scattered portions of masticated aliment prior to deglutition. Immediately on the introduction of a morsel of food into the mouth, either bitten by the incisors or otherwise, it is at once transferred to the molars, so that it shall project beyond them, outwards, against the cheek; the cheek is then pushed against it by the action of the buccinator, and the food is slowly driven across the teeth, which are rhythmically opened and closed, the tongue at the same time pushing moderately against it on the inside and so regulating the movement imparted to it by the cheek. Thus we see that the food under mastication is subjected to an equable and regulated motion; that it is placed, as it were, between two movable walls, and that by the even lateral movements of these walls, and the rhythmical vertical action of the teeth, its perfect mastication is secured. As soon as the cheek has pushed it inwards as far as it can, an interval in the rhythmical closure of the teeth takes place, and the tongue restores it to its former position, again to be pushed inwards, and so on. The equable mastication of the food is secured much in the same way as the even motion of a rod of timber, under the blade of a circular saw, secures the cutting off of pieces of equal thickness. Any one who watches himself whilst eating will at once observe the sets of rhythmical action, interrupted by short interval, in which the food is restored to its necessary position between the teeth. The third stage, that of collecting the food from all parts of the mouth, admits of no particular description.

Insalivation.—There is no separate or superadded process for insalivation; it proceeds contemporaneously with mastication, the motions which are necessary for the one supplying equally the required conditions of the other; while the food is being comminuted by the teeth, dispersed by their action to different parts of the mouth, recollected by the tongue to be again dispersed, and so on, the salivary secretion is freely mixed with it, and reduces it to a homogeneous pulp: thus mastication facilitates insalivation by breaking up the food, and insalivation facilitates mastication by softening it. As one set of acts performs the two processes, of course there are not any additional movements of the tongue to describe.

Deglutition.—When the food has attained a sufficient moisture and softness, which is appreciated by the tongue's sense of touch, it is collected into a mass, and the process of deglutition commences. Physiologists have divided this process, and the division is a good one, into three stages, which may be distinguished respectively as the *oral*, the *pharyngeal*, and the *œsophageal:* the first conducts it past the anterior pillars of the fauces, the second includes its transmission from that point through the pharynx into the œsophagus, and the third commences with its arrival at the œsophagus, and terminates with its entrance into the stomach. The first is entirely voluntary; the second is of a mixed nature, engaging partly voluntary and partly involuntary muscles, and, though practicable at will, is yet impressible on the transference to the back part of the tongue of the material to be swallowed; the third is wholly involuntary. With the two first alone the tongue is engaged, and, therefore, of these alone I shall speak.

The *first* stage is merely the reference of the ball of alimentary matter to a point on the back of the tongue, posterior to the anterior pillars of the fauces. This is effected by the pressure of the tongue against the palate, whereby the food is forced back between the two.

The *second* stage is a much more complex process, involving a more varied mechanism, and engaging in it different parts, the tongue, the pillars of the fauces, the soft palate, the larynx, and all the muscles of the pharynx. As soon as the food has passed the anterior palatine arch, that arch contracts, and by its constriction entirely prevents the regression of the food into the mouth; at the same time the base of the tongue, and with it the food, is carried further back, and a second closure takes place from the approximation of the *posterior* pillars of the fauces, produced by the contraction of the palato-pharyngeal muscles that form them: this part of the mechanism requires a little explanation. The contraction of the anterior pillars of the fauces closes the entrance into the mouth by a *constriction* or sphincter-like action: this is due to the general circular form of the constrictor isthmi faucium occasioned by the inward curvature of the upper and lower extremities of each *palato-glossus* muscle. The contraction of the palato-pharyngei is not of this nature; they have not the same inward curvature above and below, and their inferior attachments to the posterior borders of the thyroid cartilage are capable of very little approximation; when, therefore, they contract, the soft palate being fixed, they approach one another laterally like two curtains, leaving a narrow chink in the middle, wider below than above. As soon as the food has passed this point, this contraction takes place, so that the two muscles of the opposite sides almost touch, the chink between them being occupied by the relaxed uvula; the passage into the posterior nares and upper part of the pharynx is thus cut off, which has induced Dzondi to call the posterior palatine arch the *velum palati posterius*. At the same time that this is taking place, the base of the tongue is thrown back upon the epiglottis*, the larynx being drawn upwards and forwards to meet it, so that the rima glottidis is completely closed, and the food glides safely down, over the inclined plane thus formed, into the pharynx raised and dilated to receive it: the food then comes within the grip of the constrictors of the pharynx, which successively pass it downwards to the œsophagus. This process takes place so rapidly that it is difficult to trace its parts in succession, and indeed some of them, which apparently succeed one another, are in reality contemporaneous: thus, the first stage — the raising of the dorsum of the tongue to the palate — is that which mainly contributes to the inclined plane of the second stage; and the raising and carrying forwards of the larynx under the tongue is that which principally dilates the pharynx.†

The *third* stage, or the œsophageal, conducts the food to the stomach; it is of that peristaltic or vermicular nature that characterises all the succeeding movements of the alimentary canal; the muscles concerned are entirely involuntary, and the nature of the act purely reflex. The tongue is not concerned in it.

Speech. — The tongue is the instrument principally engaged in those modifications of the oral passages which give rise to articulate sounds, which, definitely grouped and combined by man, and taken as the representatives of certain objects, actions, qualities, and relations, constitute Language. The consideration of this interesting subject, however, will more appropriately fall under the article Voice, to which the reader is referred.

Morbid Anatomy of the Tongue. — The tongue is obnoxious to a variety of morbid changes, which might naturally be expected from the number and nature of the elementary tissues which enter into its formation, as well as from the diversity of the functions it has to perform, and the exposure to injury in which it is placed; — changes which may consist either in some increase, decrease, or disproportion of its normal elements, in some lesion or morbid change in those elements, or else in the superaddition of some adventitious growth.

The tongue may be affected with inflammation, hypertrophy, atrophy, induration; with ulceration, numerous morbid changes in the conditions of the papillæ; with tumours, cancer, aphthæ; and the organ, moreover, is subject to be displaced, — there is prolapsus of the tongue, the tongue may be inverted and embraced by the pharynx — swallowed; and the tongue may be unnaturally fixed by an unusual extent of frenum, the individual thus circumstanced being *tongue-tied.*

Inflammation of the tongue. — The morbid changes caused by inflammation of the tongue are modified by the structure of the organ. There is one form of this disease in which, from the extreme vascularity of the tongue and the distensibility of its covering, it swells to an enormous size with great rapidity, and subsequently recedes without suppuration: this I have ventured to call *erectile*. In other cases the tongue suppurates. The constitutional action of mercury is another cause of glossitis. I therefore divide glossitis, for its more complete consideration, into — I. Idiopathic (1. *Suppurative*; 2. *Erectile*); and II. Mercurial.

Suppurative glossitis. — This is an extremely uncommon affection. It commences with heat, swelling, induration, and some fever; matter presents itself at various lengths of time, forming a more or less circumscribed abscess. It generally occurs on one side, and points just beneath the edge of the tongue. According to Dr. Möller, of Zealand, scrofulous persons are most liable to this affection. Instances are recorded by Mr. A. Smee, Dr. Graves, Dr. Möller, and one example occurred in the practice of the author's father. This latter patient was a lady, recovering from an attack of influenza. Her tongue, which was affected principally on one side, became swollen, tender, hard, stiff, and incapable of movement. She could not speak, and swallowed with great difficulty. At length the pus was evacuated, and the tongue healed, and recovered all its functions immediately. This lady now possesses a remarkably good use of the organ.

Erectile glossitis. — This malady, though less rare than the preceding, is still quite uncommon. The morbid condition of the tongue in this disease appears to consist in an enormous and rapid distension of the organ by blood, rendering it very large, hard, and stiff. In the majority of cases it occurs in people in perfect health, and seems to be a purely idiopathic inflammation: in some cases it seems to have followed exposure to cold, and in others it was associated with febrile disorders. In this disease the first change which occurs is a perceptible enlargement of the tongue, which feels rather stiff, painful, and tender with a little difficulty in speaking, the patient being in other respects well. The case generally proceeds rapidly; in two or three hours the tongue is much larger; there is a good deal of distressing burning felt in it. Synocha, symptomatic of the local inflammation, now occurs, and goes on increasing with the glossitis, and the patient becomes anxious and alarmed. The tongue occupies now the whole cavity of the mouth, or even protrudes, and the jaws are kept apart. Mr. Martin thus describes the condition of the tongue at this stage: — "On examining the tongue, I found that it occupied a large proportion of the

* It would seem that the epiglottis is not absolutely necessary for the protection of the rima glottidis, but that the pressure of the base of the tongue over it is sufficient; as there are authentic cases on record, in which the epiglottis was quite destroyed by syphilis, and yet deglutition was never attended with any inconvenience.

† For a detailed account of this process, see Dzondi, die Functionen des weichen Gaumens. Halle, 1831.

cavity of the mouth; and I could with difficulty introduce my little finger between it and the upper jaw. It felt smooth and hard to the touch, and had a thick coating of viscid mucus: from the high degree of tension, the point presented a glistening appearance." (*Edinburgh Med. and Surg. Journal*, vol. xxviii. p. 76.) As the case advances the tongue increases still further in size, the patient cannot perform the first part of the act of deglutition, and the liquid food is obliged to be conveyed by some mechanism into the pharynx; respiration through the mouth ceases, and that through the nares is impeded: the patient is now almost on the verge of suffocation, and his distress and anxiety become extreme. Mr. Martin remarks: — "At this period respiration through the mouth was totally suspended; and he could not breathe, even through the nostrils, but with difficulty. His countenance was flushed and anxious, the pulse was fluttering, his breathing offensive: in short, he was threatened with immediate suffocation." (*Loc. cit.*, p. 77.) The condition of the tongue sometimes approaches gangrene. Mr. Hayes, in describing a similar case at an advanced stage, observes: — "It now began to look of a dark black colour, or rather as if it had been broiled over a smoky fire; indeed, I expected it would mortify." (*Memoirs of the Medical Society of London*, vol. ii. p. 193.)

I am not aware that mortification has ever resulted in these cases; neither does abscess appear to be thus produced,* which, however, may be accounted for by the fact, that these urgent cases almost always render it necessary that the organ should be freely incised on the dorsum to evacuate the distending blood, and this would prevent the formation of abscess; though in some very severe instances, where incision has not been practised, no abscess has resulted. When the inflammatory action ceases, which is immediate when the before-mentioned operation is performed, the tongue rapidly recovers, and the fever vanishes. When the tongue is incised, the quantity of blood discharged is very great.

The morbid change in the tongue does not always go to the extent above described, and then milder symptoms are produced. Dr. England mentions two mild cases, in both of which the left half of the tongue alone was affected. Dr. Graves relates a severe case, also confined to the left side, in which he says the part "appeared on the verge of gangrene." (*Dublin Hospital Reports*, vol. iv. p. 43.) De Lamalle narrates an example, in which the patient was almost suffocated in five hours from the first appearance of the malady. The tongue was more than three times its natural size; it filled the whole mouth, and protruded between the teeth. Free incisions saved the organ and the patient. Trincavellius mentions a case where it occurred in Variola; Mr. Hayes an instance, where an individual, licking an urticarious eruption, had this effect produced to a slight extent on her tongue; and the same thing, to a small degree, I have known occur from a person eating mussels.

* Since the above has been in type, a case occurring to Dr. Schneider has been published, where this form of inflammation terminated in abscess. (*Casper's Wochenschrift.* No. 23.)

Collier, Taynton, Job à Mekren, Paletta, Elbuig, Frank, and Orgill, also enumerate examples of this condition.

Dr. Craigie has described a peculiar form of glossitis, under the name of *Lingual Quinsy*, which is an extension of ordinary quinsy, or tonsillitis. The portion of the tongue involved is that bounded in front by the circumvallate papillæ, behind by the epiglottis, and at the sides by the mucous membrane passing off upon the pharynx and rami of the lower jaw. The inflammation extends down the palato-glossus muscle from the tonsils to the base of the tongue, and seems to involve the mucous, submucous, and muscular tissues. The parts are swollen, infiltrated, and stiff; the lower jaw cannot be depressed, and attempts at deglutition are not only difficult, but the completion of the act is impossible. There is an abundant secretion of ropy mucus. Dr. Craigie had one fatal case, in which he found after death, that "the base of the tongue was tumid, hard, and much distended with blood and serum infiltrated into its cellular tissue, and the parts between that and the angle of the jaw were in like manner infiltrated." (*Edin. Med. and Surg. Journal*, vol. xlii. p. 26.)

Mercurial glossitis. — Inflammation of the tongue, the result of the mercurial action, is but one symptom of the constitutional influence of that drug. The tongue in this case becomes large, soft, painful, white and furred, and much indented by the teeth along its edges: the epithelium is soft and readily removed, and the surface is apt to ulcerate. The swelling is sometimes very great and rapid. Slegel and Trincavellius each mention such a case. I believe it has never caused suppuration of the organ; but the discontinuance of the mercury is followed by complete resolution.

Ulceration of the tongue.—This is the most frequent of the morbid changes occurring in the tongue, and of it there are several species and varieties. The different species may be enumerated as, I. The Dyspeptic ulceration, or that arising from disorder of the primæ viæ; II. Indurated non-malignant ulceration; III. Gangrenous ulceration; and IV. Syphilitic ulceration.

Dyspeptic ulceration is met with in three principal forms. 1. Small circular ulcerations at the tip and along the edge of the tongue; 2. Severe and deeper ulcerations of the body of the tongue; and, 3. Aphthous ulceration.

The *small circular ulcers* of the tongue are extremely common, and have been personally experienced by almost every individual. They consist of small, circular, generally regular and well defined ulcers, which are superficial and look as if a piece of mucous membrane had been *punched* out; the edges are sharp and well defined: these ulcers vary in size from that of a pin's head to that of a split-pea, or larger; they are almost constantly situated at the tip, or edges of the tongue; they are sometimes grey, at others red; when touched against the teeth they are acutely painful, and their presence causes an abundant and constant secretion of saliva. In the commencement, however, there is no ulceration, but the malady begins by an affection of a papilla, consisting in an effusion of lymph into a fungiform papilla (hereafter to be described), and this terminates in ulceration: the papilla is at first large, yellow, and distended with lymph; in a few hours it has disappeared, and its site is occupied by an ulcer, which afterwards more or less spreads in a regular, centrifugal manner. I believe this process has never before been properly described, — persons not being aware that any thing has happened until the ulcer exists, and consequently never seeing or exhibiting the malady in the first stage; but any one, subject to these little infirmities, may satisfy himself of the truth of what I have said by carefully watching the state of his tongue from day to day.

The *severe and deep-seated ulcerations* of the tongue, arising from mere disorder of the alimentary canal, may consist of an extension of the already-described variety, or it may commence by a vesication, or an excoriation of the surface; it generally occurs in people who are debilitated from some cause or another. Mr. Lawrence relates the following characteristic case: — "A lady, between fifty and sixty, of unhealthy appearance, with a red pimply face, who had often suffered from disorder of the digestive organs, consulted me for a disease of the tongue of formidable appearance. The middle and upper part of the organ was swollen, and occupied by a deep ulcer of irregular figure and foul aspect. It was very painful, interfering with mastication and articulation. The digestive organs were much disturbed. The complaint yielded speedily and effectually to simple measures — regulation of diet, and the digestive organs, small doses of extract of henbane, and soothing local means." (Clinical Lecture, *Medical Gazette*, vol. xxxvi. p. 800.)

Mr. Lawrence mentions an instance in which rawness and severe excoriation of the tongue often repeated, the result of periodic and long-continued dyspepsia, appear to have induced true scirrhus of the organ.

Aphthous ulceration. — The ulceration is merely one stage of a peculiar morbid change, to which the tongue, in common with some other portions of the gastro-intestinal mucous membrane, is liable. The tongue, however, suffers more severely than most other parts. It is eminently the result of disordered digestion, and is accompanied with more or less fever of an atonic character. An aphthous tongue is rather swollen, tender, and furred, and has a sensation of burning heat: on its surface, scattered about irregularly, are small white bodies, resembling little masses of curd, varying in size from a split pea to a pin's-head, attached pretty firmly; these bodies, as well as the swollen state of the tongue, cause the subject of them pain and inconvenience: after a variable time these little white masses fall off, leaving the membrane on which they rested in an altered condition,—it is either raw and excoriated at these spots, the epithelium being peeled off and leaving the papillæ naked, exposed, and red; or else, the deeper elements of the membrane being affected, an ulcer is formed. These ulcers are generally more or less circular and superficial, and are in no way to be distinguished, at this stage, from the little circular ulcers already described, but aphthæ on the neighbouring portions of the tongue disclose their true nature. The white aphthous mass itself has been variously described as a *slough*, *concrete mucus*, and *albumino-fibrin*, but it consists in reality of a minute *parasitic fungus*, which attaches itself to the mucous membrane and burrows among its epithelial cells. Seen under the microscope, it is found to be composed of threads matted together like felt, and intertwining among the epithelium. Accompanying aphthæ are generally to be seen on the surface of the tongue, small vesicæ, spots of epithelium raised with a little serum underneath, and also some of the papillæ distended with fibrinous exudation — conditions to be described presently.

Indurated non-malignant ulceration.—Indurated ulcers, which are neither syphilitic nor malignant, but closely resembling scirrhus, are occasionally met with, and their doubtful character gives the surgeon not a little trouble. Mr. Lane narrates the following formidable example: — "Mr. G. B., aged 33, came to me in the month of June, 1813, with a very foul ulcer beneath the tongue, and said that he some time before had had one on the upper part of it, which he said was healed; but on examination there was a deep irregular fissure, with raised, jagged, hardened edges, communicating with the ulcer under the tongue, which, on examining with a probe, I found not only communicated with the fissure on the upper surface, but the instrument passed through the substance of the tongue, into a deep seated ulcer at the root of it, and thence into the throat. The general appearance of the disease was most alarming, bearing a very strong character of carcinoma. He experienced great pain and difficulty in deglutition, and complained that the pain had of late extended behind the ears, to the back of the head and neck." (*Medico-Chirur. Trans.*, vol. viii. p. 202.) The case, however, was not one of carcinoma, for the patient completely recovered under alterative treatment. About two years since an instance came under my own notice. A man of about 45, had been a sailor; had never had syphilis; for about six years had been labouring under a disease of the tongue, with little improvement, or permanent change, in its condition. When I saw him, the right half of the tongue was enlarged and much indurated; the left was of natural size and soft, but with few papillæ; on the right side no papillæ were to be seen, and the surface was excoriated, chapped, and in parts superficially ulcerated. He told me that at one time the left side had been diseased in a similar way. The lymphatic glands behind and beneath the jaw and down the neck were enlarged and indurated, and had been so from the first. The free application of lunar caustic to the tongue lessened the affection, and the lymphatic glands became smaller and softer; but the other side became afterwards diseased, and was relieved by the same treatment; the tongue was, however, never restored to a healthy state, though, when I last saw him, there was no ulceration. There was profuse secretion of saliva; but, with this exception, the man was remarkably healthy.

Mr. Lawrence, in his Clinical Lecture, already referred to, describes this condition of tongue. (*Loc. cit.*, p. 799, case ii.)

Gangrenous ulceration.—The tongue is liable to a peculiar gangrenous ulceration, called "Glossanthrax" or "Malignant pustule." It commences as a vesicle containing bloody serum; it gradually becomes black and bursts, and the lingual tissues beneath and around it are seen to be gangrenous; this may proceed till the whole tongue is in a state of mortification: when it exists to this degree, there is fever of a profound typhoid character, with delirium, and the patient soon dies. Audral has given an account of this disease in his Pathological Anatomy. Heyfelder narrates the case of a Prussian butcher, who, when slaughtering a diseased sheep, put the knife and held it for some time between his teeth. In two or three days the margin of his tongue was covered with black pustules. The part swelled alarmingly, and most painfully; violent fever set in, and the patient was carried off in the course of sixty hours.

I once saw a patient in low fever, who had enormous sloughing of the dorsum of the tongue, which proceeded in successive portions till a large deep excavation, that would have received half a walnut, was produced.

Syphilitic ulceration.—Hunter* strangely fell into the error of thinking that venereal ulcerations of the tongue are uncommon, whereas they are the most common to which the organ is liable; and the tongue, next to the tonsils, is more frequently attacked, in the constitutional forms of this disease, than any other portion of the mucous surface.

A *small, circular, superficial ulcer* is the most common syphilitic affection of the tongue; it begins exactly like the little ulcers of dyspeptics, from which it cannot be distinguished. These ulcers are situated principally at the tip and along the edges of the tongue. As in almost all instances of ulceration of the tongue, the ulcer is the second part of the process, and follows the deposition of fibrinous matter under the basement membrane; in this case in a single papilla, or a few contiguous ones, as I have already described. These ulcers generally do not extend, but yield to the most simple treatment; sometimes, however, they do extend, and form various sized unhealthy ulcers, deep in proportion to their extent, cupped and indurated at the base. At other times they show a tendency to run in one direction, and remain superficial: I saw an example of this in a patient who had a very narrow superficial ulcer an inch in length, originating in a small circular ulcer, and extending along the under surface of the tongue, on the left side, just at the point where the mucous membrane is reflected from that organ to the jaw: it was very superficial, and, as it progressed, it attacked the healthy membrane in its course.

Rhagades or *fissures* in the tongue are not uncommon: they are ulcerated clefts, which extend down, often to a considerable depth, into the substance of the tongue. Mr. Lawrence describes one three quarters of an inch deep; though sometimes they only form a chap in the mucous membrane: he also describes one extending the whole length of the tongue, just in its centre, in the long axis; this was deep, and with irregular ulcerated edges. When seen in the fore part of the organ, they are generally in the middle line, or nearly so; but those further back are scattered about, and just in front of the circumvallate papillæ, which is their most usual situation. They are commonly associated with an indurated and irregularly tuberculated surface of tongue — these tubercular lumps being sometimes like large fissured warts, at others glossy and smooth. The rhagades are generally red, while the surrounding tubercles are grey, or whitish, or, at other times, red and excoriated.

The *glossy tubercle*, to which I have referred, is a remarkable disease: it often forms with great rapidity, and as quickly disappears. It seems to consist in an effusion of lymph into the cellular tissue underlying the mucous membrane; this effusion is very dense, and raises and distends the surface of the tongue at the affected part above the surrounding portions; the effect is, that the complications of the membrane, which constitute the papillæ, become unfolded, and the papillæ are, as it were, *opened out*,—they form now one smooth extent, and stretch over a large surface, the faintest indications only of the papillæ being apparent, and sometimes they are totally obliterated. That this is the true explanation of these smooth tubercles is evident from the fact, that as they form, and in proportion to the distension of the membrane, the papillæ diminish and shorten; and as, under the influence of medicines, the swelling decreases, they reappear exactly in the same ratio. These tubercles have little sensation or pain, unless the surface be excoriated; they are dense, almost as hard as schirrus; their base is felt pretty deep in the substance of the tongue; their surface is polished, glossy, and whitish—they remind me of the tongue of a fish; they are generally oval or round, when smallish and single, and they are most frequently situated on the dorsum of the tongue, about half an

* Speaking of ulceration of the tongue, Hunter observes, "these are commonly supposed to be venereal; but I believe they seldom are." (*Hunter's Treatise on the Venereal Disease.* Page 337. 2nd Ed. 4to.)

inch or an inch in front of the circumvallate papillæ, and on one side of the mesial line. Sometimes they form over the whole surface of the tongue. I am acquainted with a gentleman who, at the time he was suffering from syphilitic psoriasis, got an attack of dyspepsia; in less than thirty-six hours the whole of his tongue was one mass of these tubercles, and not a papilla was to be seen; in a few days (under the influence of iodide of potassium) every papilla had reappeared, and the tongue was in every way natural. This influence of disordered stomach being the immediate and exciting cause of the manifestation of the syphilitic poison on the tongue, I have frequently noticed; a person who has a taint of lues venerea can scarcely sustain the least disorder of the stomach or bowels without its showing itself upon the tongue. These tubercles of the tongue, when left to themselves, are very apt to become fissured and form rhagades; the space between two of them is liable to be the seat of an ulcerated fissure. Deep circular ulcers sometimes form on these tubercles.

Phagedænic syphilitic ulcers are seen occasionally on the tongues of feeble debilitated people.

All these forms occur as the result of the constitutional taint of lues venerea, at various periods after the primary symptoms. I have known the glossy tubercle and rhagades occur fifteen years after the primary sore.

Cancer of the tongue. — The tongue is liable to be affected with scirrhus, having all the properties of genuine cancer. Mr. Travers has given a very graphic description of cancer of the tongue, which I shall take the liberty of quoting *in extenso.* — " This is not a smooth and firm rounded tubercle, such as is often met with in this organ, but an irregular rugged knob in its first stage, generally situated in the anterior third, and midway between the raphé and one edge. It sometimes, but seldom, extends across the middle line, although it often extends alongside of it. The hardness is unyielding, inelastic, and the mucous surface puckered and rigid. It also gives to the finger and thumb of the surgeon the sensation of solidity, or of its penetrating the entire muscular substance, being perceived equally on either surface. Sharp shoots of pain are felt through the side of the affected organ, towards the angle of the jaw and ear. The disease tends to run backwards towards the base or posterior edge. It sometimes acquires great bulk before ulceration takes place, so as to project the tongue from the mouth. In this state a female patient of mine was seen some time ago in St. Thomas's Hospital, in whom the permanent projection of the diseased organ, beyond the widely distended lips, was from three to four inches. The ulceration often extends from the edge of the tongue to the membrane of the mouth and gums, when the elevated and distended membrane at length gives way, and ulceration is rapid. The surface of the ulcer is very uneven; clean and bright granulations appearing in parts, and in others deep and sloughy hollows. The darting pain is very acute, but only occasional. There is a dull aching always present, and as constant a spitting as in deep salivation. It happens to strong and hitherto healthy persons, for the most part males from the age of forty onwards. There is generally an evening paroxysm of pain, and the nights are much disturbed by the secretion accumulating in the throat, which excites cough. Often the patient is roused by a painful compression of the tongue falling between the jaws. Speech is much affected and painful.

" Towards the fatal termination of the disease, occasional profuse hæmorrhages take place at shortening intervals, and alarm and weaken the patient, who ultimately dies tabid and exhausted, generally with symptoms of more extensive disease of the mucous membrane in other parts.

" The period at which the sublingual and contiguous lymphatic glands become affected, and the extent of their change, are very variable. I have known them form the base of the tumor, the cauliflower fungus occupying half the tongue, *i. e.* two or three inches long and one broad; after death the jaw was found covered with fungus." (*Medico-Chirurgical Transactions*, vol. xv. part i. p. 245.)

The scirrhus is not infrequently at the very margin of the tongue. Louis mentions a case where there was a little circumscribed tubercle of scirrhus, about the size of a filbert, at the edge of the tongue: it was ulcerated.

It occasionally shows itself early in life: Arnott mentions a case where it was present in a girl of fifteen.

In a subject who died of lingual cancer, dissected by myself, I found that the whole of the right side of the tongue, right tonsil, the upper part of the pharynx on the right side, and the mucous membrane, extending from the tongue to the epiglottis on the same side, were removed by ulceration, and the inner surface of the lower maxilla laid bare. The other half of the tongue was healthy, and only the ulcerated edge was scirrhous. The lymphatics were enlarged, and of a greenish-yellow colour: they conained pus.

Tumours of the tongue. — A variety of tumours have been met with in the tongue.

Fatty tumours have been found by Mr. Liston on the under surface of the tongue. Mr. Hale Thomson exhibited to the Westminster Medical Society, in 1839, a fatty tumour which he removed from the side of the tongue. It consisted of fat contained in a cyst.

Encysted tumours. — Many of the so-called instances of ranula* have been abundantly proved by Dupuytren, Breschet, and Malgaine to be simply serous cysts, and not obstructed salivary ducts. They consist of dense membranous cysts, containing a thick albuminous

* The consideration of *ranula* belongs to the morbid anatomy of the salivary glands, and not of the tongue.

fluid, and not inspissated saliva. They are situated in the cellular tissue immediately under the mucous membrane, where they sometimes grow to an enormous size. Mr. Earle has described curious little vesicular tumours, which he found in the tongue of a boy: — "Clusters of very minute semitransparent vesicles pervaded the whole thickness of the tongue, occupying nearly one-half, and projected considerably both above and below that organ. The slightest injury caused these to bleed profusely, and in some places the clusters were separated by deep clefts, which discharged a fetid, irritating sanies." (*Medico-Chirur. Trans.*, vol. xii. pt. ii.) The tongue was quite restored by the use of internal medicine.

A *mulberry-like tumour* has been described by Mr. Probart. It formed on the tip of the tongue of a boy four years of age. It was of a peculiar granulated appearance, resembling a half-ripe mulberry, feeling hard and free from pain. It grew gradually: at two months it was the size of a nutmeg; but after that, in five weeks, it rapidly increased till it was of the bigness of a hen's egg, protruding nearly two inches beyond the lips, which were separated widely by it, preventing the little patient taking any thing but spoon meat, and that with difficulty. It was highly vascular, and bled profusely from innumerable vessels, which nothing but the cautery would arrest, when amputated. There was no return of the disease.

Polypus-like tumours have been met with on the tongue, consisting of a fleshy mass, like the rest of the organ, attached to it by a pedicle. Louis mentions one of these about the size of a nutmeg, which he removed from the tongue of a young man eighteen years of age: it was situated on the middle of the dorsum of the tongue. A more remarkable example is described by Dr. Huie. The case was that of an old maiden lady, in whom a tumour formed, about three months after a catarrh and inflammation of the fauces, upon the root of the tongue, and gradually increased for twelve months, when "the smooth rounded form of the tumour conveyed, at first sight, the idea that it was of an encysted kind; but, upon examination with the finger, it was found to be as hard and unyielding as the substance of the tongue itself, and evidently of the nature of polypus." (*Edinb. Med.-Chirur. Trans.*, vol. iii. p. 72.) It filled nearly the whole pharynx, and moved with the tongue, to which it was attached by a pedicle. Ligature was subsequently applied, by which it was removed. "The tumour, which is in the Museum of the Royal College of Surgeons (of Edinburgh), was of an oval form, weighed exactly an ounce, and measured five inches in its long, and four in its short, circumference. It was broadest opposite the insertion of the pedicle, which entered at the distance of an inch from the upper part of the tumour. A longitudinal incision, which has been made into it, displays a firm cartilaginous nucleus, as large as a chestnut, surrounded by a fibro-cartilaginous structure, forming the rest of the tumour." (*Loc. cit.*, p. 76.) I strongly suspect that all these pedunculated tumours of the tongue are hypertrophied fungiform or circumvallate papillæ.

Hypertrophy and prolapsus of the tongue. — This is a singular affection, which usually commences in infancy, and is sometimes congenital. It generally begins and progresses slowly by an enlargement of the organ within the mouth; it afterwards projects permanently between the lips, and then advances more rapidly, and the tongue, which was before of normal, though hypertrophied, structure, becomes parched and fissured on the upper surface, and ulcerated beneath. Sometimes the amount of tongue that is protruded is enormous. The os hyoides and larynx are drawn up, whilst the jaw is depressed, and the incisors are pushed out in a horizontal direction.

Dr. Wells, of Columbia, has given a good case, of which the following is a condensed description. The patient was a little girl, six years old, with an enormous enlargement of the tongue; otherwise she was in good health, and a fine robust girl. The following are the dimensions and state of the tongue at the time: — length, as it remained at rest and hung down over the chin, from the superior incisors to the apex, two and a half inches; circumference just in front of the lips, six inches; breadth, from one angle of the mouth to the other, a little more than two inches. It had undergone a very considerable change in structure, was much more dense than natural, and not subject to change in its dimensions by the action of its own muscles, or, if at all, very slightly so. Its motions otherwise were sufficiently free: upper surface smooth; inferior covered with the cicatrices of old ulcers, several of which, where the tongue rested upon the alveolar processes of the lower jaw, were but imperfectly healed; colour darker than natural. Within the mouth the tongue had undergone no apparent change except a moderate increase in width and thickness. The front teeth had been displaced from the lower jaw by the long-continued pressure of the tongue. The lower lip was folded downwards. The anterior portion of the superior maxillary bone had undergone a slight curve upwards; the inferior a much greater curve downwards; so that when the back teeth came in contact, the front were an inch asunder, or, rather, the space between the upper teeth and the corresponding alveolar processes below was something more than an inch. This condition of tongue commenced by an attack of glossitis in infancy. A portion of the organ was removed by ligature, and she completely recovered.

Mr. Crosse mentions a girl of six years old, in whom the tongue was prolapsed three or four inches; and this was completely reduced by pressure and leeching.

Mr. Liston has described an instance in which the tongue projected three or four inches from the lips of a young man, nineteen years of age, the disease having been congenital. It was of a brown and livid colour, rough, granulated, and fissured, and beneath the mucous membrane were abundant venous plexuses. This tongue was liable to periodic intumescence, when it became much larger, was very painful, and bled profusely. Mr. Liston has stated his belief, that, from the periodical enlargement and diminution of the tongue, and the erectile tissue being evident in many parts of its surface, the mass was partly composed of a structure resembling aneurism by anastomosis.

These hypertrophied tongues, when curtailed by the knife or ligature sufficiently to be taken within the teeth, generally soon accommodate themselves to the form and dimensions of the oral cavity.

Professor Lassus has given instances, where this has been accomplished by means of bandaging and compressing the tongue.

Atrophy of the tongue. — I am not acquainted with any instance of atrophy of the entire organ, nor with any unassociated with paralysis. It generally shows itself in cases of hemiplegia, when the tongue does not immediately recover, and results from diminished nutrition, the consequence of want of exercise, being confined to the paralysed half, just as the arm and leg of the affected side become atrophied under the like circumstances. It is more obvious, however, when the hypoglossal nerve alone is the seat of injury or disease. Professor Budd mentions, in his lectures, an instance which fell under the care of his brother, Dr. William Budd, of a man who sustained a stab in the neck, dividing the external carotid artery and hypoglossal nerve on the left side. The artery was secured, and the man recovered with palsy of the left side of the tongue. At the end of some weeks that half of the tongue was much wasted, and all the movements of the organ were performed by the other half. The atrophy was confined to the muscular element of the organ: taste and touch remained uninjured. — (*MS. Notes of Lecture.*)

Dupuytren mentions an example of atrophy and paralysis* of the left half of the tongue caused by the pressure, upon the hypoglossal nerve, of an hydatid cyst in the anterior condyloid foramen.

In this condition, as well as in hemiplegia, the state of the tongue is remarkable from one part of the organ being passive, while the other is active. As long as it is at rest, the diminished size of the affected side is all that is observable. When the tongue is extruded, it is thrust over towards the affected side,—it emerges from the mouth obliquely, because the extruding muscles of the sound side have no antagonists. The paralysis of the intrinsic transverse muscular fibres gives rise to another phenomenon, which I have never seen described,—it is the curved form of the tongue itself; the raphé in the middle of the tongue is not straight, but curved, and the concavity looks towards the affected side. These fibres, whose function it is to make narrow, and, by that, to lengthen the tongue, only act on one side, and only half the tongue is thus elongated; and this, being adherent to the other half which sustains no elongation, is thrown into an arch, on the same principle as the curving of the compound wire in a Bréguet's thermometer.

Diseases of the papillæ.—In considering the diseases of the surface of the tongue, authors have not taken sufficient care to consider the true anatomy of the papillary membrane, and their descriptions are consequently loose and ill-defined. It is of the utmost importance to state where the morbid changes are situated; whether above or beneath the basement membrane; whether it is the epithelium, or the vessels and sub-basement areolar tissue that have undergone the alteration.

The papillæ are liable to hypertrophy, atrophy, effusion of blood or of fibrine into their interior; they may be denuded of their epithelium, or that covering may be stained or rendered opaque, producing what is called *fur.*

Hypertrophy of papillæ. — The *circumvallate* papillæ are liable to be enlarged, the central portion forming a little tumour, rising above the surrounding ring of membrane. Dr. Andrew Ferguson has described them as increasing to the size of peas. There are generally several affected at once. I have seen them increased to this size, as well as some of the *fungiform* papillæ at the back of the tongue, in an individual suffering from scrofulous enlargement of the tonsils. The polypoid tumours (retaining the same form and proportions as these papillæ, though greatly enlarged), I believe to be nothing more than hypertrophied fungiform, or circumvallate papillæ.

The *conical* or *filiform* papillæ are liable to a peculiar change, which has, to the best of my knowledge, never been described. It consists in an enormous increase in their epithelial element, forming long cylindrical rods; in fact, *hairs:* the only apparent change in these organs being superficial to the basement membrane. I am in possession of the notes of two examples of this malady. For the first I am indebted to my brother, Dr. James Salter. He observes, "My patient was an old gentleman, impoverished by intemperance; his general health was good, and he was now temperate: for some years he had suffered from the peculiar affection of the tongue under which he now laboured. This affection was a great elongation of the conical and filiform papillæ, in all parts of the tongue where these abound: they were eight or ten times their natural length, and over-lapped each other, like the pile of plush, or long velvet. The hypertrophy appeared to be entirely in the long axis; there was no increase in circumference, and they were little larger at their base than the apex. They were soft, and lay over lapping each other on the sur-

* In both these cases the *muscular motion* was the only function implicated, which, as Dupuytren observes, is interesting physiologically; taste and ordinary sensation not being in the least affected.

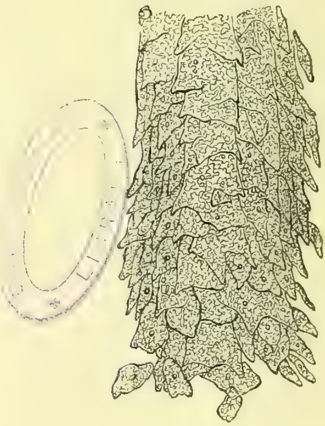
face ; and by smoothing the finger over the tongue they could be brushed from one side to the other. Their colour was deep Vandyke-brown, and they were most numerous in the centre of the tongue. They looked exactly like little brown hairs. Sensation and taste were both a good deal damaged." To my friend, Dr. Joseph Bullar, I am indebted for the other instance. His patient was an old lady of sixty-five ; she had been subject to constipation, for which she was in the habit of taking strong purgatives. The tongue was large, vascular, and the papillæ of all kinds prominently marked. It looked in an irritable condition, as if sympathising with a congested mucous membrane. On the middle and back of the dorsum was a patch of hypertrophied filiform papillæ, of a dark sepia colour, or rather of the brown colour of a dark typhoid tongue. These filamentous growths were removed by forceps, and some were sent to me, from which I made the accompanying drawings. The specimens that I received were very dark, almost black : I have some of them in my possession now, nearly or quite half an inch long ; their texture was very compact, and their shape cylindrical, with hardly any trace of tapering. They all, as seen by the microscope, possessed a retrorse imbrication of the same character as ordinary filiform papillæ (*fig*. 764.). The epithelium did not contain any granular pigment, but the colour appeared to pervade the whole cell, which was evenly stained and semi-transparent. In *fig*. 764. is seen a papilla, or hair, at full length, and in *fig*. 765. a portion of another, showing the imbrication of the epithelium.

Fig. 764.

A portion of hypertrophied filiform papilla, showing its length and true hair character. Mag. 25 and 80 diameters.

The *Scarlatina* tongue contrasts remarkably with the preceding ; for here the deeper elements of the papillæ are principally the seat of change. In scarlet fever the capillaries of the papillæ, in common with the sub-basement vascular system of so large a portion both of the internal and external surfaces of the body, become turgid, and the papillæ themselves — not so much their epithelium — become en-

Fig 765.



A portion of hypertrophied papilla, showing well the retrorse imbrication of its epithelium. Mag. 200 diameters.

larged and red. In the early stages of the fever this change is concealed by the *fur* (which is a sodden and opaque condition of epithelium), as it regards the filiform papillæ, —*fur* being, in all cases I believe, confined to these and the papillæ conicæ. Not so the fungiform papillæ ; for these are exaggerated and bright red. The result is, that the surface is a combination of thick white cream-like fur and red projected spots, the former being most conspicuous where the filiform papillæ abound — the central portions of the tongue, — and the latter in the regions of the papillæ fungiformæ — the edges and tip of the tongue. These fungiform papillæ look like the achænia scattered on the surface of the fruit of the strawberry. As the disease advances, the epithelial covering is shed, and only a thin transparent epithelium remains : the papillæ are consequently red and bright all over the surface, which is clean, rough, red, and raw-looking in every part.

Atrophy of the papillæ is occasionally met with. Mr. Lawrence mentions the case of a person in whom, from habitual drinking, the tongue was, for the greater part of its surface, destitute of papillæ: it was white, smooth and opaque on the surface. I have already mentioned the obliteration of the papillæ in the glossy tubercle of syphilis, and it also occasionally occurs in lues venerea, independent of the tubercle.

I have seen the tongues of old people remarkably bald, especially as it regards the filiform papillæ: as a general rule, these papillæ are less prominent in the aged.

Effusions into papillæ.—The *fungiform* papillæ are liable to be the seat of little *extravasations of blood.* I am acquainted with a medical gentleman who has himself frequently had this trivial affection. It has always occurred to him in the night, and is indicated by a sharp pain, as though the tongue were stabbed by a red-hot needle, caused, doubtless, by the pressure of the blood upon the nerves in the papilla. Upon examining the tongue a papilla is seen to be distended into a minute capsule of blood, at first red, and afterwards black. The coagulum is absorbed in a few days, and the papilla resumes its former appearance.

Lymph of a *grey* or *ash-colour* is apt to be deposited in and under the papillæ, in the tongues of persons tainted with syphilis. When this occurs on the dorsum, it gives a grey speckled appearance to the patch, some of the papillæ in the spot being unaffected. It looks as though this circumscribed surface had been rubbed with chalk. The patches vary in size from a split pea to a fourpenny piece. Occurring under the tip and along the under edge of the tongue, the appearance is a whitish even spot, of gristly texture, and not presenting a speckled appearance, the papillæ here being invisible, and covered up uniformly with epithelium. This is the most common situation for these spots, which after a time become fissured, and ulcerate.

Lymph, effused into a fungiform papilla, is the commencement of the common little circular ulcer on the tip and edge of the tongue. I have snipped off, and examined under the microscope, one of these papillæ. It was filled with a yellow, opaque, granular, sub-fibrous mass. The papilla is not only enlarged by this effusion of lymph, but is altered in form; its pedicle is elongated, and its head flattened. When the papilla does not ulcerate, but returns to a healthy state, its contents are absorbed, it diminishes in size, and the summit of the papilla becomes pitted in the centre. It then gradually assumes its natural size, shape, and colour. This may be easily seen by watching, every few hours, a patient's tongue through an ordinary pocket lens.

Denuded papillæ.—The papillæ are occasionally denuded by the effusion of serum between the basement membrane and epithelium, by which this latter is raised into a blister, and is subsequently rubbed off by the motions of the tongue, leaving the red naked papillæ beneath. This denuded surface is red as compared with the surrounding, and smooth, but when viewed through a magnifier the small naked papillæ are seen to be regular and perfect. This surface is not ulcerated, but feels sore when touched. I have lately seen a patch, the size of a shilling, thus denuded in a patient suffering from diarrhœa.

Fur.—The *fur* of the tongue is the epithelium, principally of the conical and filiform papillæ, variously altered. It is most abundant where these papillæ are most plentiful, and it will be found, by inspecting minutely a furred tongue, that the fungiform papillæ have undergone very little, if any, change. I believe, with M. Piorry, that the fur of the tongue is chiefly dependent upon the condition of the saliva and mucus of the mouth: and, holding this view, it is easy to understand how it is that the filiform and conical papillæ are principally affected; they hang among the fluids of the mouth, exposing a large superficies in proportion to their bulk; their surface is uneven and broken, and this, with the imbricated state of the epithelial particles, make them quickly and thoroughly imbibe, and become saturated with, any fluid into which they are immersed. In all this they contrast with the fungiform papillæ, whose surface, in proportion to bulk, is small, and whose epithelium is spread in a thin, *even* sheet, smoothly over their surface. It must have been observed by every one, that the colour of the papillæ of a brown typhoid tongue is identical with that of the *sordes* around the teeth, which is nothing more than the saliva and mucus, in which these papillæ have been bathed, inspissated, and is doubtless the source of their colour. The white fur consists of a white, opaque, soft, sodden epithelium, which, when viewed under the microscope, differs from the epithelium in its ordinary state, in no other particular than its opacity. When the fur is brown, the epithelium presents the appearance of being simply and evenly stained. There are no opaque pigmentary particles in the cavity of the cell.

The various amounts and characters of the fur; the different arrangements of it in different diseases and at different stages; the alterations, form, and size of the tongue, &c.; all symptomatic of morbid changes elsewhere, and belonging rather to the physician than the morbid anatomist, I shall not stop to describe. But it must not be forgotten that, in health, many of these conditions are natural to some persons: in some, the tongue is habitually furred, in others it is chapped, ragged, and irregular.

The *healing* and *reparation* of the papillary surface of the tongue is not a little remarkable. I have known the surface of the tongue, after it has been immensely disfigured, especially in syphilitic cases, by tubercles, and rhagades, and ulcers, restored almost to its former condition. After ulceration it would seem that the cicatrix contracts to a mere line, while the surrounding mucous membrane becomes extended, and either fresh papillæ form, or else the minute simple papillæ increase in dimensions, and become complicated, for the papillary surface is ultimately quite restored.

I shall conclude these observations on the morbid anatomy of the tongue with some remarks on faulty positions which the organ occasionally obtains. I have already spoken of *prolapsus* of the tongue, and there now remain for consideration — *tongue-tie*, *tongue-swallowing*, and *adhesion of the tongue to adjacent parts.*

Tongue-tie. — This is a congenital malformation, consisting in the frænum extending too far forwards and being short, thus tying down the tongue behind the incisor teeth of the lower jaw. This may occur to any degree, from an amount that is scarcely observable, to the complete tying down the tip of the tongue behind the necks of the middle incisors of the lower jaw. The frænum generally consists simply of a small amount of fibrous tissue contained in the fold of mucous membrane; but it sometimes contains fibres of the genio-glossus, which occasionally extend a considerable way forwards: in the former case the frænum is thin, in the latter it may be of some thickness. When left to nature the tie gradually lengthens, and, at the same time, recedes, and any unusual thickness arising from the presence of muscular fibres gradually lessens. This condition, to a slight extent, is very frequent, and appears to be hereditary. The cases are, however, extremely rare where the frænum is so short as to interfere with sucking, mastication, deglutition, or articulation.

Tongue-swallowing. — This arises from the opposite of the last condition: the movements of the tongue are too free; it can be inverted, and its apex thrown back into the pharynx, which embraces it, and thus closes the aperture leading to the lungs, and symptoms of suffocation are the result. It most frequently happens to infants. It is enumerated by writers on Medical Jurisprudence, as one of the modes of suicide among negroes. Dr. Gordon Smith, Majendie, and Beck refer to cases of it. Mr. Crosse tells of an instance, where it could be performed at pleasure without the slightest inconvenience.

Adhesions of the tongue. — Bernard relates an instance, in which adhesions, of the thickness of two lines and a half, had agglutinated the lateral parts of the tongue to the internal surface of the cheeks, to the extent of more than an inch on each side. These adhesions had succeeded an inflammation in the inside of the mouth and tongue, the circumference of which had ulcerated; they interrupted the functions of speech and mastication. M. Bernard divided them by a single clip of the scissors.

Necrosis of the hyoid bone. — The only instance of disease of the hyoid bone with which I am acquainted, is one related by Mr. Spry. The disease was necrosis, the result of extended ulceration, which commenced in the throat, and continued till the bone was laid bare and dead. It was then *expectorated entire.* The patient died several weeks afterwards. The bone was entirely deprived of periosteum, irregular on its surface, and in a perfect state of necrosis.

[Since this Article has been in the press I have become acquainted with a discovery of Prof. Kölliker's, that the muscular fibres in certain situations are bifurcated and branched. In a letter to Prof. Bowman he says, that this is brilliantly exhibited by the muscles of the tongue, and he gives a pen and ink illustration of the method of branching. There can be no doubt about a fact so detailed by such an authority, but I must confess that I have not recognised the appearances described.]

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(*H. Hyde Salter.*)

TOUCH.—The sense through which we take cognisance of the palpable properties of bodies. The term is used, however, in two meanings, between which it is requisite to maintain a due discrimination. In its extended acceptation, it implies our consciousness of *all* those sensory impressions, which are neither olfactive, visual, auditory, nor gustative; and it is therefore designated as the *general sense*, in contradistinction to those, which are considered as *special senses*. In its most limited application, on the other hand, it is used to designate that modification of the general sensibility, which is restricted to the tegumentary surface, or to some special portion of it, and which serves to excite definite ideas in our minds respecting the form, size, number, configuration, weight, temperature, hardness, softness, &c., of objects brought within its cognisance. The use of the sense of Touch, in the acquirement of these ideas, is, as we shall see hereafter, a very complex process; involving not merely the discriminating employment of the proper organs of touch, but also the assistance of muscular action, and of the information derived from it by the "muscular sense."

General Sensibility. — The most universal of all the qualities or properties of matter (that, in fact, upon which our notion of it is founded) is *resistance*; and it is of this quality that we find the power of cognisance most extensively diffused through the body, and most universally possessed by all beings endowed with consciousness. It would seem to require nothing else than the presence of nerves connected (directly or indirectly) with sensorial centres; for there does not appear to be a need of any special organisation, surrounding the peripheral extremities of these nerves, in order that they may receive and transmit impressions. Thus any unusual pressure on a nerve in its course is at once perceived by the mind, — not, however, *as* pressure, but as a disagreeable or painful sensation, which gives no indication of the mode in which it was excited. The nerves of smell, sight, and hearing, are not thus affected by mechanical irritation, no manifestations of pain being exhibited when they are pinched, torn, lacerated, &c.; and the general sensibility which these organs of sense possess is dependent upon other nerves. The nerves of taste, however, exhibit the same susceptibility to tactile impressions, as do those of touch; and hence we have an additional proof of the very close affinity of these two senses (See TASTE).

The only condition requisite for the exercise of "general sensibility," beyond the integrity of the nervous apparatus, is the adequate supply of oxygenated blood. Wherever sensory nerves exist, we find them accompanied by blood-vessels; and no non-vascular tissue possesses in itself the least degree of sensibility. Thus, in the epidermis, hair, nails, cartilage, and tooth-substance, neither nerves nor blood-vessels exist, and we find these tissues completely insensible. In tendons, ligaments, fibrous membranes, and in other parts whose function is purely mechanical, we find very little vascularity, and extremely little sensitiveness to ordinary impressions; it is remarkable, however, that although the tissues, whose function it is to resist tension, are scarcely impressible by cutting, burning, &c., they cannot be unduly stretched without considerable pain. So, also, the serous and synovial membranes are not in the least susceptible of ordinary tactile impressions in their healthy state; but they become acutely sensitive when inflamed. It does not at all follow, however, that the sensibility of a part should increase with its vascularity; for we find that some of the most vascular organs in the body are the least sensitive, the supply of blood which they receive having some purpose entirely different. Thus the sensibility of the muscles is by no means proportionate to the large amount of blood which they receive; and even the substance of the brain (like that of the nerves of special sensation) is destitute of this property. So, again, the mucous membranes lining the interior of the several viscera, though supplied with blood even more copiously than the skin, are very far inferior to it in sensibility. The dependence of this endowment, however, wherever it exists, upon the continued circulation of the blood, is at once made apparent by the results of its suspension; thus, when the main artery of a limb is tied, there is a diminution of the sensibility both of its surface and of its substance, which is so exactly proportioned to the degree in which the supply of blood is diminished, and the recovery from which takes place so precisely in accordance with the establishment of the collateral circulation, that we cannot doubt that, if the supply of blood were completely cut off, sensibility would be entirely suspended. The numbness produced by cold, in like manner, is partly due to the stagnation which it occasions in the capillary circulation in the skin; though it is doubtless in part attributable to the immediate depressing influence of the cold upon the vital endowments of the nervous apparatus itself.

The general sensibility of the body may be called into activity by impressions received from objects external to it, or by causes originating in itself; and the consequent sensations are sometimes distinguished as "external" and "internal." These designations are by no means logically correct; for *all* sensations must originate in causes *external to the recipient mind;* whilst, on the other hand, in order that *any* sensation may be felt, a certain condition of the corporeal organism must first be produced; and this condition may be precisely the same, whether it be immediately dependent upon changes originating in the body itself, or upon changes impressed upon it from some agency external to it. Still, however, the terms "external" and "internal" sensations are sufficiently convenient, and sufficiently free from the probability of misconception, to justify the physiologist in the employment of them; and they will be accordingly employed in our present enquiry.

The *external sensations* received through this medium all require the *absolute contact** of the body which excites them, with the impressible part; and in this respect, therefore, there is an exact correspondence between the general sensibility and the sense of taste.

The *force* with which the impression is made, is judged of by the intensity of the sensation and the depth to which it is felt; whilst the *size* of the object is in some degree estimated by the extent of surface over which its contact is perceived. Both these estimates, however, are extremely vague, when they depend only upon the general sensibility of the body; we shall hereafter see how much more precise they become, when the impressions are received through the skin, which is the special organ of touch, and when they are aided and corrected by the muscular sense. Still we find that the different modes in which external objects affect even the general sensibility, produce a very marked diversity in the character of the sensations. Thus the feeling called forth by a *prick* is of a very different kind from that which arises from a *blow;* both, again, are very distinct from that produced by a steady uniform pressure; and all these are very different from the sensation of *stretching* or *tearing.* In the case of a prick, we have an intense impression made on the sensible part; but this is limited to a very small spot; whilst the impression of a blow is made with a like intensity over a much larger area.† In the case of steady pressure, on the other hand, the impression is made over a large surface, but is less intense; whilst in stretching and tearing, the mechanical condition of the nerves of the part operated on is affected in a manner precisely opposite to that in which it is acted on by pressure. The sense of *shock*, derived from a blow extending over a large surface, is very distinct from that of the mere blow, and may be experienced when little or no pain is felt, as from the "wind" of a shot; and nearly allied to this is the peculiar *jar* which is experienced, when the shock is transmitted in such a manner as especially to affect the solid casing of the nervous centres, — as when we jump from a height, without sufficient care to alight in such a manner as to deaden the concussion by the elasticity of the feet, &c. A succession of slight impulses rapidly following one another, gives rise to the peculiar sensation of *thrill;* which, though most readily excited when the impressions are made upon the skin, may be received through the internal organs also as when we hold a vibrating body between the teeth.

These and other well-marked differences in the kind of information received through the general sensibility of the body, seem obviously attributable rather to diversities in the mode in which the impressions are made, than to any differences in the nature of the impressions themselves, the character of the fibres receiving them, or the endowments of the ganglionic centres in which these fibres terminate. And hence we seem to have a greater right to conclude, that the various affections of general sensibility, which are usually ranked under the common head of *internal sensations*, however unlike they may be one to another, are really derived from impressions which do not mutually differ so essentially as do those of the special senses from each other and from the general sense. Of this kind are the sensations of hunger and thirst, the "besoin de respirer," the genital sense, the sensation which calls for the expulsion of the urine and fæces, nausea, the feelings of oppression and of "sinking" at the stomach, burning, itching, tingling, formication, and others. However different these are from each other, when but slightly or moderately excited, they all merge, when more strongly called forth, into the simple consciousness of pain; and it is further common to them all, that the nerves through which they are excited are the same as those which communicate the impressions that excite tactile sensations, and that mechanical irritation of any of these nerves occasions pain. To the foregoing may be added the "muscular sense," whereby we are informed of the degree of effort put forth by a muscle; and the sense of "fatigue," which seems to be a modification of this. We are not conscious either of effort or fatigue in the actions of any of the muscles over which the will has no control, such as the heart, the muscular walls of the intestinal canal, &c.; nor in the case of those whose actions are purely rhythmical, as those of respiration. It is, in fact, only when the will is exerted, either in increasing the force of their contractions, or in antagonising them by the operation of some other muscles, that we become conscious of effort; and we shall hereafter see that this sense is most important, in enabling us to proportion the amount of force we exert to the resistance to be overcome, and in guiding us with regard to the direction in which exertion is required. A sense of effort and of fatigue seems also to be excited in the sensorium by the mental operations of which the cerebrum is the instrument; especially when these mental operations are no longer spontaneous, or carried on with facility, but when they require a more or less

* There might seem to be an exception to this statement in regard to heat and cold, which are perceived when their source is at any distance that allows its radiations to affect the temperature of the body itself. But, as will presently be shown, it does not appear that the sense of temperature forms part of the *general sensibility* of the body; the power of appreciating heat or cold, *as such*, being limited to the special organs of touch.

† There can be no doubt that a multitude of *pricks* made at the same moment, in sufficiently close proximity to prevent them from being separately distinguished, would be felt as a *blow;* this being the only sensation which is received from the numerous incisions simultaneously made by the scarificator used in cupping, when it is applied to the parts of the skin endowed with the least discriminating power.

potent exertion of the will to keep them in activity. As we have every reason to believe that all mental exertion, like muscular force, involves (in our present state of being) a disintegration of the substance of its instrument — the brain, — there is no difficulty in understanding that this disintegration, when carried beyond a certain point, may excite the sense of fatigue (see SLEEP), just as the "besoin de respirer" is felt after we have withheld our respiratory movements for a few seconds, or hunger when there is a deficiency of nutritious matter in the circulating current. It has been said by Mr. Mayo, "that the frame is in the completest health and condition, when the internal sensations are not excited; the healthiest self-feeling being an absence of all inward sensation." This, however, is scarcely a sufficient account of the fact; for, in the highest condition of health, there is not only an absence of all uneasy feeling, but a general sense of buoyancy and resiliency, difficult to describe in words, which may be characterised as the positive sense of *well-being*. So, on the other hand, without any positive or distinct sensation, there may be a consciousness of general discomfort, which has been expressively termed by the French *malaise*. These two sensations may probably be considered as originating in the condition of the blood; the first being an indication of its purity, and of its perfect adaptation to the wants of the system; whilst the second would seem to proceed from a slight depravation of its quality, resulting not unfrequently from the imperfect elimination of excretory matters, such as is not sufficient in itself to constitute an actual disease.

Having thus passed in review the principal manifestations of the general sensibility of the body, and the conditions under which they occur, we have now to proceed to the investigation of the sense of touch, as exercised by the organs specially adapted for the reception of tactile impressions.

SENSE OF TOUCH.

Special Organs of Touch. — The peculiar endowments of the tegumentary surface, which enable us to draw from the impressions received through it, information of so much more varied and definite a character than we can derive through any of the structures which it invests, appear to consist principally, so far as the organ itself is concerned, in its greater sensibility (that is, in its greater aptitude for being affected by slight impressions), and in its greater power of communicating distinct impressions from points in close proximity; but a large part of our information is dependent upon our power of giving motion to the tactile organ, and thus of increasing the force and variety of the impressions which we derive through its surface, as well as of receiving impressions of an entirely different kind, from the action of the muscles by which that motion is given. Thus, if we simply bring a solid body into contact with the point of the finger, we gain but little information of the nature of its surface, whether rough, smooth, or polished; and we can judge nothing of its form, except in regard to that part of it in actual contact with the fingers; and even this is but vaguely appreciated. This information may be rendered somewhat more precise by *pressing* the object against the finger; as we shall then feel the impression made by elevations, points, or roughnesses, if they be sufficiently prominent and wide apart from each other; whilst from the degree of muscular force we exert, and from the amount of yielding of which we are conscious in the object itself, we judge of its hardness, softness, elasticity, &c. But our power of discrimination is immensely increased, when we *move* the tactile surface on the body to be examined, or *vice versâ*; for, from the succession of impressions then made, we obtain our best idea of the character of the surface of the object; whilst by the combination of the tactile impressions with the muscular sense, we judge of the relative positions and connections of its different parts, and of the form of the whole. But besides this, we find that impressions may be derived through the skin, which are not referable to a mere exaltation of its common sensibility, being apparently of a different character from any of which we become conscious through other structures; such, especially, are sensations of temperature. Still there would seem no sufficient cause for ranking even these in a distinct category from the ordinary tactile impressions; for the feeling of heat or cold does not differ more from that of roughness or smoothness, than does the colour of the object, as seen by the eye, from its form as distinguished by the same organ.

The different parts of the cutaneous surface are endowed with tactile sensibility in very different degrees; and this variation seems closely to correspond with the degree of development of that *papillary* structure, which may be regarded as the special organ of touch, strictly so called. These *papillæ* are most elevated and numerous on the tip of the tongue and the points of the fingers; are less so on the palms of the hands and the soles of the feet; are comparatively small and few on the integument of the limbs, and on several parts of the trunk can scarcely be discovered at all. They are described by Messrs. Todd and Bowman* as having an average length in man of $\frac{1}{100}$th of an inch; and a diameter at their base, where they spring from the cutícle, of about $\frac{1}{250}$th of an inch. Their form is somewhat conical, tapering off to a slightly rounded point. Their surface (after the removal of the epidermis) appears to be composed of the basement membrane of the cutis itself; and their interior is composed of fibrous tissue, vessels, and nerves. In each papilla we find a small arterial twig, derived from the arterial plexus of the cutis; this, advancing towards the apex of the papilla, subdivides into two or more capillary ves-

* Physiological Anatomy, vol. i. p. 410.

sels; and these, forming loops whose convexity lies in the summit of the papilla, reunite into venous radicles, which discharge their blood into the venous plexus of the cutis. "The vascularity of the papillæ," as Messrs. Todd and Bowman correctly remark, (*loc. cit.*), "is such, that their presence and relative size may be determined simply by the depth of the colour imparted to the skin by a good injection of its vessels; the vascularity of the integument is, therefore, in general terms, proportioned to its perfection as an organ of touch." With regard to the nervous supply of these papillæ, however, it is less easy to speak with confidence. It is derived, like the sanguiferous, from the plexus in the substance of the cutis, lying parallel to the surface; the tubular fibres ascend, to all appearance *singly*,* from this plexus into the papillæ; but their mode of termination or return are not distinguishable with certainty. The following are the results of the inquiries of Messrs. Todd and Bowman on this point. "In regard to the presence of nerves in the papillæ themselves, we can affirm that we have distinctly traced solitary tubules ascending among the other tissues of the papillæ about half-way to their summits, but then becoming lost to sight, either by simply ending, or else by losing the white substance of Schwann, which alone enables us to distinguish them in such situations from other textures. . . . . We have in numerous instances failed to detect any nerves at all within the papillæ, when such were plainly visible at their base, and when, consequently, the chemical agent employed could scarcely have destroyed their characteristic structure had they been present. We incline to the belief that the tubules, either entirely or in great measure, lose the white substance when within the papillæ."* With these statements, so far as they go, the writer's own observations are in entire accordance; but he thinks that from the appearances presented by sections examined by *reflected* instead of by *transmitted* light, it may be inferred that the nervous tubules in the tactile papillæ undergo a change somewhat similar to that which is said by Wagner to take place in the nervous tubuli of muscle; namely, that whilst the white substance of Schwann is not traceable beyond a certain point, the central axis is continued further, and that this breaks up into minuter fibrillæ, which form loops, like those of the capillary blood vessels, returning into the tubular fibre itself.

In the lower animals, as in man, it may be observed that the papillary structure is especially developed on those parts of the tegumentary surface which are especially endowed with tactile sensibility, and the impressions received through which are of important use in finding the movements of the instruments of locomotion. Thus in the quadrumana generally, both the hands and feet are thickly set with papillæ; and in those which have a prehensile tail, the surface of this organ possesses them in abundance. In the carnivorous and herbivorous mammalia, whose extremities are furnished with claws or encased in hoofs, we find the lips and the parts surrounding the nostrils to be the chief seat of tactile sensibility, and to be copiously furnished with papillæ; this is especially the case with those which have the lips or nostrils prolonged into a snout or proboscis, as in the pig, the rhinoceros, the tapir, and the elephant. In the mole, too, the papillary structure is remarkably developed at the extremity of the snout. The only part of the skin of birds on which tactile papillæ have been discovered is on the under surface of the toes, and on the web of the palmipedes, where they obviously receive impressions, which guide the prehensile and other movements of the feet. It is probable, however, that the very sensitive skin which covers the greater part of the mandibles in the duck tribe, is furnished with papillæ; the tactile impressions received through this part, when the bill is plunged into mud &c., being the chief means by which the presence of food is discovered. In many lizards a papillary structure is found on the under surface of the toes; and in the chameleon it exists, also, on the integuments of its prehensile tail. In the soft skinned batrachia, an imperfect papillary structure is more extensively diffused over the surface; but on the thumb of the male frog, and probably on that of other batrachia, there is an extraordinary development of papillary tissue at the season of sexual excitement, large papillæ being formed all over it. This organisation is obviously connected with the extraordinary prehensile propensity which is then displayed by the animal, and which enables him to keep the female in his grasp during the whole period of the discharge of the ova, in a manner which no voluntary effort could effect. In serpents and chelonians, no papillary apparatus has yet been detected; and in fishes and invertebrata its presence has not been ascertained, although it would appear that certain parts, especially the tentacula around the oral orifice, are endowed with a high degree of tactile sensibility.*

But it is not only on the tegumentary surface of the exterior of the body, that tactile sensibility is particularly acute; nor is the papillary apparatus restricted to it alone. In the tongue of man, we find the sense of touch remarkably developed, especially at its tip; and of the papillæ with which its surface is beset, it is probable that some are the instruments of tactile sensibility; whilst others minister to the gustative sense. (See TASTE.) So it is probable that in all animals which have a soft fleshy tongue, furnished with papillæ, and serving as the organ of taste, this organ is the instrument of tactile sensibility also.

* Op. cit. p. 412.

* The movements of these organs, or such as are excited through contact with them, can scarcely be in themselves regarded as a sufficient indication of their tactile sensibility, as they may be purely reflex, without involving consciousness of the impression.

Besides the papillary apparatus, however, we find certain animals endowed with special organs of touch, which are constructed upon a very different plan; consisting of a rod or filament, which is in itself insensible, but which is connected at its base with nervous fibres, in such a manner that any motion or vibration communicated to it must be transmitted to them. Such are the long stiff hairs which are known as the "whiskers" of the feline tribe, and which are so particularly large in the seal; these are also highly developed in many of the rodentia, such as the hare and rabbit; and it has been proved by experiment, that if they be cut off, the animal loses in great degree its power of guiding its movements in the dark. Thus Mr. Broughton found that whilst a kitten whose whiskers were entire was capable of threading its way blindfold out of a labyrinth in which it was designedly placed, it was totally unable to do so when its whiskers were cut off; for it then struck its head repeatedly against the sides, ran against all the corners, and tumbled over steps placed in its way, instead of avoiding them as it did prior to the loss of its whiskers.* In animals whose hairs are their important instruments of touch, a true papilla, copiously furnished with nerves and blood-vessels, is found to project into the bulb of each hair. The jointed appendages to the head, known as *antennæ* and *palpi*, which are possessed by most articulated animals, are undoubtedly instruments of touch, whatever sensory impressions they may receive in addition. The antennæ, when prolonged, serve to guide the movements of the animal; the impressions which they receive at their extremities being communicated to the nerves at their base, just as a blind man judges by the stick held in his hand of the proximity of obstacles to his progress.† On the other hand, the palpi appear to minister to the cognisance of objects brought into the neighbourhood of the mouth, and to have for their chief office to guide in the selection of food. But while there are many facts which seem to indicate that the antennæ minister to the sense of hearing, there are others which appear to point to the palpi as the special instruments of that of smell.

Conditions of the Sense of Touch. — The sense of touch, strictly so called, is exercised under conditions essentially the same as those through which the general sensibility of the body is affected. It is requisite, in the first place, that the bodies, of whose presence it takes cognisance, should be brought into actual contact with the tactile surface; the only exception being in regard to the temperature of objects, the influence of which may be communicated by radiations from a distance. This difference, however, does not indicate any fundamental diversity such as some have imagined to exist, between the sense of temperature and that of resistance; for, in each case, that which is perceived by the mind is the impression made upon the sensory organ; and the change in this is excited in the one case by pressure, and in the other by heat or cold. The same organ appears to be adapted to take cognisance of both classes of impressions; a feeling of one kind being excited, when its condition is altered by pressure; and a feeling of a different kind, when its temperature has undergone a change under the influence of calorific radiations. And the difference between these classes of sensations is not greater than that which exists among others, — whether of a general or a special kind, — which we know to be transmitted by the same nerve-fibres. Yet it would seem that, whilst there is no sufficient reason for supposing impressions of contact and of temperature to be transmitted by different nerve-fibres, we must admit that some of these fibres, either in virtue of their own constitution, of the locality of their central termination, or of the apparatus with which they are furnished at their peripheral origin, are endowed with a greater readiness to receive and transmit one or the other class of impressions. For we find that the parts whose tactile sensibility is the most discriminating, are not always those by which the keenest appreciation of changes of temperature is obtained. And, in like manner, the occasional occurrence of cases of paralysis, in which there is a total loss of one kind of sensation, whilst the other is preserved, or in which one is diminished beyond all proportion to the other, seems to show that such a change may take place in the nerve-fibres, as may indispose them to the reception and transmission of one class of impressions, whilst they are still capable of actively responding to the other.

After what has been said of the necessity of the supply of blood, for the active exercise of common or general sensibility, and of the vascularity of the special tactile organs, it is not requisite to lay any further stress on this point, in relation to the sense of touch, strictly so called. Another important condition, which is probably common to the whole sensory apparatus of the warm-blooded animal, and which has been already noticed under the head of Taste, is a temperature not too far removed from that which is natural to the body. It has been shown by Professor E. H. Weber, that if the fingers or the lips be immersed for half a minute or a minute in water heated to 125°, or cooled to 32°, the power of tactile discrimination is so much impaired, that the power of distinguishing between a

* London Medical and Physical Journal, 1823.

† The author is acquainted with a blind gentleman who exhibits a remarkable dexterity in the use of his stick in guiding his movements; and he has been informed by him, that much of his power of discrimination depends upon the flexibility, elasticity, &c. of this instrument, so that, when he has chanced to lose or break the one to which he has been accustomed, it is often long before he can obtain another that shall suit him so well. This circumstance seems to throw some light upon the remakable varieties of conformation in the antennæ of insects; as it may well be imagined that each is adapted to receive and to communicate impressions of a particular class, adapted to the wants of the species.

hot or cold fluid or solid body is for the time completely lost, a feeling of pain alone being experienced, which is the same whether the body be hot or cold. This, too, he found to be the case, when, instead of applying the heat or cold to the peripheral extremities of the nerve, he acted on its trunk. For this experiment the ulnar nerve was selected, as its trunk, at the elbow, lies immediately beneath the surface. After immersing the elbow in a mixture of ice and water for about sixteen seconds, Professor Weber observed that a peculiar painful sensation was experienced along the under side of the fore-arm, the wrist, the little finger, and the inner side of the ring-finger. This pain had no resemblance to that of cold. On continuing the immersion, the pain increased considerably, and eventually became almost intolerable; then it gradually diminished, and the middle and ring-fingers became numb, as if "asleep," had no longer the power of distinguishing between heat and cold, and could only imperfectly perceive the contact and pressure of bodies.*

The *exercise* of the sense of touch may be first considered under its simplest mode, namely, that in which the object is simply applied to the tactile organ; and in this we have specially to consider the power of *Tactile Discrimination*, and the *Sense of Temperature.*

Tactile Discrimination. — A very ingenious method was devised by Professor Weber†, for determining the relative power of tactile discrimination in different parts of the skin, which is by no means accordant with their general sensibility. His mode of ascertaining this, was to touch the surface with the points of a pair of compasses, guarded by bits of cork or sealing-wax; the eyes being closed at the same time, the legs of the compasses were approximated to each other; until they were brought so near that the points could be no longer felt to be distinct from each other. The smallest distance at which this can be perceived (entitled "the limit of confusion," by Dr. Graves), is found to differ remarkably on different parts of the cutaneous surface; and the comparison of these diversities affords us the means of estimating, — *not* their relative tactile sensibility (for this it cannot measure), — but their relative discriminating power. The figures in the first column of the following Table represent these distances, as determined by Professor Weber on his own person, stated in *Paris lines.* The inquiry has been more recently pursued by Professor Valentin ‡, whose results on the whole correspond very closely with those of Weber. He found, however, a considerable extent of individual variation; some persons being able to distinguish the points at half, or even one-third of the distances required by others. In the following table, the second column expresses the *maxima* of the "limit of confusion," the third column the *minima*, and the fourth column the mean of all the observations made by Professor Valentin; it will be observed that his maxima correspond almost exactly with the measurements of Professor Weber on his own person. In the fifth and sixth columns are shown the relative acuteness and relative obtuseness of the discriminating sense in different parts, calculated from the mean results; "the limit of confusion" (0·483) at the tip of the tongue being taken as 1·000. Thus the co-efficient of the *acuteness* of the discriminating sense in the palm of the hand, calculated by this standard, is 0·126; that of its *obtuseness* is 7·930. The co-efficient of acuteness for the crown of the head, is 0·050; that of obtuseness, for the same part, is 19·827. The co-efficient of acuteness for the middle of the dorsal spine is 0·020; that of its obtuseness is 50·086. Or, in other words, its acuteness is only $\frac{20}{1000}$ths that of the tip of the tongue; its obtuseness fifty times as great.

Similar experiments, with the like results, have been made by M. H. Belfield-Lefèvre*; and from all these, the following general propositions may be laid down:— 1. On almost any part of the integument, the interval between the two points is more clearly distinguished, when the line which joins them is *transverse* (*i. e.* perpendicular to the axis of the body or member), than when it is *longitudinal*, or parallel to that axis. According to Weber, however, the tips of the fingers and of the tongue constitute an exception to this rule; the discriminating power being greatest in them, when the line joining the points of the compasses is longitudinally directed. 2. When two points, applied *simultaneously* to any part of the integument, are clearly distinguished, the distance which separates them seems to be greater, in proportion to the acuteness of the discriminating sense in the part of the surface which is the subject of examination. Thus, as Weber remarks, if the points of the compasses, set at a distance of two or three lines, be applied to the cheek just before the ear, and be then moved gradually towards the angle of the mouth, the points will seem to recede from one another, in consequence of the increase of the discriminating sense in the parts to which they are applied. 3. When the two points are *successively* brought into contact with the skin, they seem to be at a greater distance from each other than if they are simultaneously applied; and, in general, the distance will seem greater in proportion to the interval between their application. 4. Two points applied on different sides of the median line, seem more remote from one another than two points equally distant, but applied on one and the same side of the median line; in other words, the power of discrimination is greater when the two points are applied on the two sides of the median line, than when they are both applied on the same side. 5. If two parts of the tegumentary surface be

* Müller's Archiv. 1847, p. 342.

† De Pulsu, Respiratione, Auditu, et Tactu, Annotationes Anatomicæ et Physiologicæ. Auct. H. E. Weber. Lipsiæ, 1834.

‡ Lehrbuch der Physiologie des Menschen, Band ii. S. 566.

* Recherches sur la Nature, la Distribution, et l'Organs du Sens Tactile. Paris, 1837.

TABLE.

Part of Surface.	Weber's measurements.	Valentin's Measurements.			Relative acuteness.	Relative obtuseness.
		Max.	Min.	Mean.		
	I.	II.	III.	IV.	V.	VI.
Tip of the Tongue - - - - - - -	½	0·50	0·40	0·483	1·000	1·000
Palmar surface of 3rd phalanx of fore finger -	1	1·00	0·50	0 603	0·802	1·248
Do. do. middle finger -	...	1·00	0·37	0·706	0·685	1·461
Do. do. ring-finger -	...	1·00	0·60	0·723	0·669	1·496
Do. do. thumb - -	...	1·00	0·50	0·725	0·667	1·500
Do. do. little finger -	...	1·00	0·50	0·733	0·659	1·517
Red surface of under lip - - - - - -	2	2·00	0·50	1·500	0·322	3·130
Do. upper lip - - - - - -	...	2·00	0·50	1·520	0·318	3·145
Palmar surface of 2nd phalanges of the fingers -	2	2·00	1·25	1·558	0·310	3·223
——— 1st ——— -	...	1·75	1·50	1·650	0·293	3·414
Middle of the dorsum of the tongue - - -	4	4·00	1·50	1·916	0·252	3·964
Dorsal surface of the 3rd phalanges of the fingers	3	3·00	1·75	2·125	0·227	4·397
Portion of the lips not red - - - -	4	4·00	1·50	2·208	0·219	4·568
Tip of the nose - - - - - - -	3	3·00	0·50	2·250	0·215	4·655
Edge of the tongue an inch from the tip - -	...	4·00	1·50	2·478	0·195	5·127
Lateral surface of the dorsum of the tongue -	...	4·00	1·50	2·500	0·193	5·172
Palmar surface of the metacarpus - - -	3	3·00	1·75	2·625	0·184	5·431
End of the great toe - - - - .	5	5·00	3·00	3·250	0·149	6·724
Metacarpal joint of the thumb - - - -	4	4·50	2·00	3·333	0·145	6·896
External surface of the eyelids - - - -	5	5·00	2·50	3·833	0·126	7·930
Palm of the hand - - - - -	5	5·00	3·00	3·833	0·126	7·930
Dorsal surface of 2nd phalanx of thumb - -	5	5·50	2·75	3·893	0·124	8·054
Do. do. fore finger -	...	5·50	2·75	3·893	0·124	8·054
Do. do. middle finger -	...	5·50	2·75	3·900	0·124	8·069
Do. do. little finger -	...	5·50	2·50	3·943	0·122	8·158
Do. do. ring-finger -	...	5·50	2·75	3·971	0·121	8·216
Centre of the hard palate - - - - -	6	6·00	2·00	4·042	0·120	8·363
Mucous membrane of lips close to the gum -	9	9·00	2·00	4·125	0·117	8·535
Skin of cheek over buccinator - - - -	5	5·00	3·25	4·541	0·106	9·395
Skin of cheek over anterior part of malar bone -	7	7·00	3·00	4·620	0·105	9·559
Dorsal surface of the 1st phalanges of the fingers	7	7·00	4·00	4·917	0·098	10·173
Prepuce - - - - - - - -	...	6·00	4·00	5·100	0·095	10·552
Dorsal surface over the heads of metacarpal bones	8	8·00	3·25	5·250	0·092	10·862
Skin of cheek over posterior part of malar bone -	10	10·00	3·00	5·286	0·091	10·936
Plantar surface of metacarpal bone of great toe -	...	7·00	5·00	5·875	0·082	12·155
Lower part of forehead - . - - -	10	10·00	4·00	6·000	0·081	12·414
Back of the hand - - - - - - -	14	14·00	3·50	6·966	0·069	14·412
Lower part of hairy scalp in occipital region -	12	12·00	6·00	8·292	0·058	17·156
Surface of the throat beneath lower jaw - -	15	15·00	3·00	8·292	0·058	17·156
Back of the heel - - - - - - -	10	10·00	8·00	9·000	0·054	18·621
Pubes - - - - - - - - -	...	14·00	3·00	9·200	0·052	19·035
Crown of the head - - - - - - -	15	15·00	5·50	9·583	0·050	19·827
Patella and neighbouring part of thigh - -	16	16·00	6·00	10·208	0·047	21·120
Areola around nipple - . - - -	...	20·00	9·50	12·066	0·040	24·964
Dorsum of foot near the toes - - - -	18	18·00	7·50	12·525	0·039	25·914
Axilla - - - - - - - - -	...	14·00	12·00	13·000	0·037	26·897
Upper and lower extremities of fore arm - -	18	18·00	7·00	13·292	0·036	27·501
Back of the neck near the occiput - - -	24	24·00	8·00	13·292	0·036	27·501
Upper and lower extremities of leg - - -	18	18·00	9·00	13·708	0·035	28·361
Penis - - - - - - - - -	18	18·00	10·00	13·850	0·034	28·655
Acromion and upper part of arm - - -	18	18·00	6·00	13·866	0·034	28·688
Sacral region - - - - - - - -	18	18·00	7·50	14·958	0·032	30·948
Sternum - - - - - - - -	20	20·00	8·00	15·875	0·030	32·845
Gluteal region and neighbouring part of thigh -	18	18·00	10·50	16·625	0·029	34·397
Middle of fore arm, where its circumference is greatest - - - - - - - -	30	30·00	8·75	17·083	0·028	35·344
Middle of thigh, do. - - - - -	30	30·00	9·00	17·633	0·027	36·482
Middle of cervical vertebræ - - - - -	30	30·00	7·00	18·542	0·026	38·362
Five upper dorsal vertebræ - - - -	24	24·00	11·00	19·000	0·025	39·310
Lower part of thorax, and over lumbar vertebræ	24	24·00	11·50	19·912	0·022	44·758
Middle of the dorsal vertebræ - - - -	30	30·00	11·00	24·208	0·020	50·086

selected, whose relative position is subject to variation (such as the two eyelids, the two lips, &c.), and the two points of the pair of compasses be applied respectively to these two surfaces, the distance which separates them will seem to be much greater than if the two points rest at the same time on one or the other surface. 6. The same holds good, according to Weber, when the two points are applied to parts of the surface, which, though in continuity with each other, differ remarkably, either in structure, in function, or in the use habitually made of them; thus, the points will be more clearly distinguishable, and will therefore seem to be more distant from each other, when one is applied to the inner surface and the other to the red outer surface of the lips, than when they are both applied to the latter, although its discriminating power is much greater than that of the former; and the same holds good of the margin and dorsum of the tongue, the palmar and dorsal surfaces of the last phalanges of the fingers, &c. 7. The discriminating sense is more acute in the integuments of the head, than in those of the trunk; and on the face, its acuteness diminishes as the distance from the mouth increases. 8. The tactile discrimination of the integuments of the limbs augments with the distance of the part from the axis of the body; it is less in the integuments of the trunk, than in those of the members.

The power of tactile discrimination may be conceived to depend in part upon the mode in which the ultimate nerve-fibres are distributed in the skin, being greater in proportion as contiguous parts are supplied from distinct central sources, and less when the central terminations of their nerve-tubes are the same. Thus, if two impressions be made along the course of the *same* nerve-tube, they will not be felt as two, but as one; and this probably holds good of the parts of the integument supplied with branches from the central axis of any one tube. On the other hand, whenever two impressions be made upon two distinct nerve-tubes, or on the branches proceeding from them, they will probably be felt to be double; and the distance at which these impressions seem to the tactile sense to be, appears to have a relation to the distinctness of the central connections of these nerve-tubes, as appears from the fact that the "limit of confusion" is less across the median line than on either side of it; that it is less between two parts (such as the lips and eyelids) whose nervous supply is *known* to be distinct, than on either part separately; and that it is less between two parts whose nervous supply may be *presumed*, from their difference of function, to be distinct (as the inner and outer surfaces of the lips), than on either part separately. Moreever, it would not seem to be improbable that one use of the *plexuses* from which the limbs are supplied, is to produce such an intermingling of the fibres from different ganglionic centres, that contiguous portions of the integument shall be connected with centres very remote from each other, and their discriminating power thus augmented. No such intermingling takes place in the nerves which supply the trunk, and the tactile discrimination of its integument is (as we have seen) vastly inferior to that of the extremities. Thus it may happen that the *common sensibility* of two parts may be the same, whilst their power of *tactile discrimination* may differ considerably; and we may even have the common sensibility greatest where the tactile discrimination is least,—as we experience, for example, on the integument of the face, which is far more sensitive to a blow, and especially to a "fillip," than is the integument of the palmar surface of the fingers, although greatly inferior to them in discriminating power. The actual nervous supply, and the consequent sensibility, of a part, may be greater in such cases; but the unity, or close approximation, of the source from which this proceeds, may prevent its discriminating power from augmenting in the same proportion.

In like manner, we find that the tactile discrimination of different parts bears no relation whatever to that peculiar modification of common sensibility (which yet appears the exclusive attribute of the external integuments) through which the feeling of "tickling" is excited. For the parts which are most susceptible to this feeling, such as the axillæ and the soles of the feet, are possessed of a very low degree of discriminating power, and those which possess this power in the highest degree (such as the tips of the fingers) are the least "ticklish." Further, it is worthy of notice that the parts through which that peculiar sensation, which we have termed the genital sense, is specially excited,—namely, the penis and the mammary areola,—are remarkable rather for the obtuseness than for the acuteness of their power of tactile discrimination.

That it is only through the skin and those parts of its internal reflexions which are in closest proximity with it (especially the lining of the mouth and nostrils), that we can discriminate tactile impressions, appears from this; that although the internal mucous and serous surfaces, the fibrous membranes, and the parenchyma of many organs, &c. &c., are all capable of becoming acutely sensible to pain when irritated or inflamed, yet no foreign substance is ever distinctly felt by the touch through these parts. Thus, although a sensation of a pleasing or a painful nature is excited by certain substances immediately upon being swallowed, all consciousness of their presence (so far as it is dependent upon the sense of touch) soon ceases, and cannot be again recalled by the utmost exertion of the will. Further, a foreign substance, lodged in the alimentary canal, or in the trachea, may give rise to the greatest possible distress, through the irritation it produces; but though it thus acts upon the nerves of the parts immediately in contact with it, these nerves convey no idea to the sufferer of the shape or size of the body, or of any other of its physical qualities, concerning which we receive information through the sense of touch.

Sense of Temperature. — This sense is called into action when there is a *difference* between the temperature of the sensory organ and that of the surrounding medium, or of substances with which it is specially brought into contact. It is one of which the intensity is determined, more perhaps than that of any other sensation, rather by the *relative* than by the *absolute* condition of the body which excites it. Thus, if one hand be immersed for a time in hot water, and the other in cold, and both then be plunged into tepid water, this will seem cool to the former and warm to the latter. So, again, a person coming out of cold air into an atmosphere of moderate temperature, derives from it the feeling of genial warmth, whilst another, coming into the very same atmosphere from one much hotter, complains of its chillness. Again, when the temperature of different substances is compared by the hand, the sense is not so much influenced by the absolute amount of caloric possessed by each, as by their power of imparting cold or heat to the sensory organ. Hence substances which are good conductors (such as metals or marble) are felt to be colder than those which conduct heat badly (such as wood), although really of the same temperature, because they draw off the heat of the sensory surface more rapidly; whilst, on the other hand, if both be warmer than the sensory surface, the best conductors will seem to be the hottest, because their caloric is most readily imparted. Further, the sense of temperature is influenced in a remarkable degree by the *extent* of surface on which the impression is made. Every one is familiar with the fact that hot water in which a single finger may be held without inconvenience, will be felt intolerably scalding when the whole hand is immersed in it. And it has been shown by Professor Weber, that if one vessel of water be heated to 98° and another to 104°, and the whole of the hand be immersed in the former, while the finger alone is immersed in the latter, a wrong judgment of their relative temperatures will be probably given, that which is really the cooler being pronounced the hotter, on account of the larger extent of surface on which it acts. This mistake was made in some of his experiments, when the difference was as much as *eight* degrees; the cooler water being at 98°, and the hotter at 106°, and yet the former being esteemed the hotter. So, again, the immersion of the entire hand enables minute differences of temperature to be detected, which could not be recognised by the immersion of a single finger. By the former method, a difference of only one-third of a degree may be distinguished; the entire hand being immersed, repeatedly and successively, in two vessels of water, differing only that much in their relative warmth. But it is remarked by Professor Weber, that these minute differences are best detected when the medium examined does not fall short of, or exceed very considerably, the usual temperature of the body; just as the ear can best perceive a difference of tone in sounds which are neither very acute or very grave.*

It is a remarkable fact, discovered by Professor Weber, that the left hand is in most persons more sensible to variations of temperature than the right. Thus, when the hands of a person lying in bed, and having exactly the same temperature, are plunged each in a separate vessel of hot water, the left hand is believed to be in the hotter medium, although the water in which it is immersed is really one or two degrees colder than the other. This difference is the more remarkable, as the power of tactile discrimination is usually greater in the right hand; and it is attributed by Professor Weber to a difference in the thickness of the epidermis, the left hand usually having a thinner epidermis than the right, especially in the palm, because it is less used. But this will only apply to the hand; and since (as will be presently shown) we possess a greater power of discriminating *pressures* through the entire surface of the left side than through that of the right, it would seem much more probable that there is an *original* difference in the tactile endowments of the two sides respectively. There is certainly a strongly marked difference between different parts of the trunk in regard to their sensibility to temperature, as is experienced by those who sponge themselves over with cold water immediately on leaving their bed in the morning. In the writer's case, the parts most sensitive to the cold are in the centre of the dorsal region behind; in front, between the lower end of the sternum and the umbilicus; and the corresponding portions of the flanks. These spots are among the parts of the integument least possessed of tactile discrimination; and yet the cold sponge passing over them seems to be much lower in temperature than when it is applied to other parts.

Some further experiments have recently been made by Professor Weber, to determine whether the sense of temperature is received through any other channel than the sensory apparatus contained in the integuments.† The first means of which he availed himself for deciding this question, was that afforded by the results of accident or surgical operations, in which a portion of skin has been left deficient. Thus, in three cases in which a large portion of the skin had been destroyed by a burn, and in which healing had not advanced so far as to renew the organ of touch, it was found that no correct discrimination could be made between two spatulas, one of them at a temperature of from 48° to 54°, the other of from 113° to 122°, which were brought into

* He further remarks, that the comparison between two temperatures can be best made when the impressions are not *simultaneously* made upon two different parts, but are made *in quick succession* upon the same part; as mentioned hereafter to be the case in regard to weights.

† Müller's Archiv. 1849. Heft, iv. s. 273—283.

contact with the denuded surface; so that one of these patients thrice affirmed that he was being touched with the cold body when it was the warm, and the reverse. But when the spatula was in one instance made somewhat warmer, and was brought into contact with the unskinned surface, the patient felt, not *heat* but *pain*. Another means of gaining information on this point is afforded by the ingestion or injection of a large quantity of warm or cold fluid into the stomach or intestinal canal. Thus Professor Weber states, that after drinking a tumbler of water at 32°, he felt the cold water in the mouth, in the palate, and in the pharynx, as far as the limits of the sense of touch; but that the gradual passage of the cold water into the stomach could not be perceived. There was, it is true, a slight sensation of cold in the gastric region; but as it only occupied the situation of the anterior wall of the stomach, it was attributable to the abstraction of heat from the abdominal integuments in contact with this. In an opposite experiment, the author drank quickly three glasses of milk, the temperature of the first of which was 158°, that of the second 145°, whilst that of the third was intermediate between the two. The sensation of heat could not be traced lower down than that of the cold in the previous experiment. At the moment when the fluid entered the stomach, there was a feeling which remained for some time, but which could not be distinguished as heat, being mistakeable for cold. In order to ascertain the sensations produced in the large intestine by cold water, an injection of 14 ozs. of water of the temperature of 65° was thrown up the rectum, but scarcely any sensation of cold could be perceived from it. In another instance, 21 ozs. of water at the same temperature was thrown up, without any resulting sensation of cold. In both these cases, on the return of the enema a few minutes afterwards, a distinct feeling of cold was experienced at the anus. When water of so low a temperature as 45½° was injected, the first feeling excited was a sensation of cold in the immediate neighbourhood of the anus, and then a feeble movement in the bowels; but a little time afterwards, there was a faint sensation of cold, especially in the anterior wall of the abdomen. This sensation, however, remained after the return of the water; and may hence be attributed to the abstraction of warmth from the abdominal integuments, which was proved to take place, the temperature of the surface being lowered 3 degrees. So, again, if the cavity of the nose be filled with cold water, the coldness is only perceived in the parts of the cavity which are most endowed with the proper tactile sense, namely, the neighbourhood of the nostrils and of the pharynx; and it is not at all discernible in the higher part of the cavity, which is especially subservient to the olfactive sense. [*See* SMELL.] But when the water injected is very cold (*e. g.* 41°), a peculiar pain is felt in the upper part of the nasal fossæ, extending to the regions of the forehead and lachrymal canals; this pain, however, is altogether different from the sense of coldness.

From the foregoing experiments it appears fair to conclude, that the sensory nerves have no power of receiving impressions arising from difference of temperature, unless those impressions are communicated through a special organ; but they afford no adequate ground for the supposition, that a set of nerve-fibres is provided for their transmission, distinct from those which minister to common sensation. This conclusion is confirmed by the fact, that we cannot excite impressions of heat or cold by direct application to the trunks of nerves which we know must conduct such impressions. Thus the parts of the skin immediately beneath which lie large nerve-trunks, are not more sensitive to moderate heat or cold than any other part; whilst a greater degree of either is felt as pain, not as a change of temperature. Thus, as we have already seen, a mixture of ice and water, applied over the ulnar nerve, affects it in fifteen seconds, and produces severe pain, having no resemblance to cold, such as cannot be excited by the same cold applied to any other region. So the nerve of the tooth-pulp is equally and similarly affected by water of 43° and of 112°; either application causing a pain exactly similar to that excited by the other, or that produced by pressure.*

We have now to consider those more complex modes of exercise of the sense of touch which require the conjoint exercise of the "muscular sense;" and as this is a modification of the general sensibility, which may perhaps be regarded as being as special or peculiar in its relations to the muscular system as the sense of touch (properly so called) is to that of the skin, it will be desirable to examine, in the first instance, into its *modus operandi*.

Muscular Sense. — It may be stated as a general fact, that all voluntary muscular contraction must be guided and controlled by sensation; and in the majority of cases, the controlling sensation is derived from the muscles themselves, of whose condition we are rendered cognisant by the sensory nerves with which they are furnished. The proof of this necessity is furnished by the entire want of power to make or sustain voluntary efforts, when the guiding sensation is deficient. Thus, in complete anæsthesia of the lower extremities, without loss of muscular power, the patient is as completely unable to walk, as if the motor nerves had also been paralysed, unless the deficient sensorial guidance be replaced by some other; and in similar affections of the upper extremities, there is a like inability to raise the limb or to sustain a weight. But in such cases, the deficiency of the "mus-

* It is remarkable that the same should be true of the impressions received through the skin itself, when they pass beyond certain limits of intensity; thus, the sensation produced by touching frozen mercury is said to be not distinguishable from that which results from touching a red-hot iron.

cular sense" may be made good by the visual; thus, the patient who cannot walk, because he cannot feel either the contact of his foot with the ground, or the muscular effort he is making, can do so if he *looks* at his limbs ; and the woman who cannot feel the pressure of her child upon her arms, can yet sustain it as long as she keeps her eyes fixed upon it, but no longer,—the muscles ceasing to contract, and the limb dropping powerless, the moment that the eyes are withdrawn from it. There are two groups of muscular actions, however, which, although as voluntary in their character as the foregoing, are yet habitually guided by other sensations than those derived from the muscles themselves. These are, the movements of the eyeball, and those of the vocal apparatus. The former are directed (as Dr. Alison has well shown *) by the visual sense, by which the action of the muscles is guided and controlled in the same manner as that of other muscles is directed by their own "muscular sense;" and hence it happens that, when we close our eyes, we cannot move them in any required direction, without an effort that strongly calls forth the muscular sense, by which the action is then guided. In persons who have become blind after having once enjoyed sight, an association is formed by habit between the muscular sense and the contractile action, that enables the former to serve as the guide after the loss of the visual sense ; but in those who are born *perfectly* blind, or who have become so in early infancy, this association is never formed, and the eyes of such persons exhibit a continued indefinite movement, and cannot by any amount of effort be steadily fixed in one spot, or be turned in any definite direction. A very small amount of the visual sense, however, such as serves merely to indicate the direction of light, is sufficient for the government of the movements of the eye-ball.

In the production of vocal sounds, again, that nice adjustment of the muscles of the larynx, which is requisite to give forth determinate tones, is ordinarily directed by the auditory sense; being learned in the first instance under the guidance of the sounds actually produced ; but being subsequently effected voluntarily, in accordance with the mental conception (a sort of inward sensation) of the tone to be uttered, which conception cannot be formed, unless the sense of hearing has previously brought similar tones to the mind. Hence it is that persons who are born *deaf*, are also *dumb*. They may have no malformation of the organs of speech ; but they are incapable of uttering distinct vocal sounds or musical tones, because they have not the guiding conception, or recalled sensation, of the nature of these. By long training, however, and by imitative efforts directed by the muscular sense of the larynx itself, some persons thus circumstanced have acquired the power of speech ; but the want of a sufficiently definite control over the vocal muscles is always very evident in their use of the organ. It is very rarely that a person who has once enjoyed the sense of hearing, afterwards becomes so *completely* deaf, as to lose all auditory control over his vocal organs. An example of this kind, however, has been made known to the public by a well known author, as having occurred in himself; and the record of his experiences * contains many points of much interest. The deafness was the result of an accident occurring in childhood, which left him for some time in a state of extreme debility; and when he made the attempt to speak, it was with considerable pain in the vocal organs. This pain probably resulted from the unaccustomed effort which it was necessary to make, when the usual guidance was wanting; being analogous to the uneasiness which we experience when we attempt to move our eyes with the lids closed. His voice at that time is described as being very similar to that of a person born deaf and dumb, but who has been taught to speak. With the uneasiness in the use of the vocal organs was associated an extreme mental indisposition to their employment; and thus, for some years, the voice was very little exercised. Circumstances afterwards forced it, however, into constant employment; and great improvement has subsequently taken place in the power of vocalisation, evidently by attention to the indications of the muscular sense. It is a curious circumstance, fully confirming this view, that the words which had been in use previously to the supervention of the deafness, are still pronounced (such of them, at least, as are kept in employment) as they were in childhood ; the muscular movements concerned in their articulation being still guided by the original auditory conception, in spite of the knowledge derived from the information of others, that their pronunciation is erroneous. On the other hand, all the words subsequently learned are pronounced according to their spelling; the acquired associations between the muscular sensations and the written signs being in this case the obvious guide.

The perception of "effort" which we derive through the impressions made on the muscular sense, is one which, as we shall presently see, is of immense value, in combination with simple tactile sensation, in informing us of the sensible properties of external objects. In its simplest exercise, however, it enables us to appreciate the degree of muscular force which is being exerted ; and excites in our minds our most definite idea of *power*. It is true that we might, by the exercise of our other senses, have arrived at the conception of a tendency in bodies to attract one another, or to communicate motion one to another ; but the notion of the *force* with which they do so is entirely founded, directly or indirectly, upon

* Anatomical and Physiological Inferences from the Study of the Nerves of the Orbit, in Trans. of Roy. Soc. Edinb., vol. xv.

* See the "Lost Senses," by Dr. Kitto; vol. i. chapters 2 and 3.

the conception of the muscular exertion which would be required to produce or to antagonise the movement. Thus it is, too, that when we are about to make a muscular effort, the amount of force which we put forth is governed by the mental conception of that which will be required, as indicated by the experience of former sensations; just as the contractions of the muscles of vocalisation are regulated by the conception of the sound to be produced. Hence if the weight be unknown to us, and it prove either much heavier or much lighter than was expected, we find that we have put forth too little or too great a muscular effort.

It is through the "muscular sense," in combination with the visual and tactile, that those movements are regulated, which are concerned alike in ordinary progression, and in the maintenance of the equilibrium of the body. That the visual sense has, in most persons, a large share in this regulation, is evident from the simple fact that no one who has not been accustomed to the deprivation of it can continue to walk straightforwards, when blind-folded, or in absolute darkness, towards any point in the direction of which he may have been at first guided. But the blind man, who has been accustomed to rely exclusively upon his muscular sense, has no difficulty in keeping to a straight path; and moves onwards with a confidence which is in remarkable contrast with the gait of a man who has been deprived of sight for the occasion only. In fact, as Mr. Mayo has well remarked *, in our ordinary movements, "we lean upon our eyesight as upon crutches." And when our vision, instead of aiding and guiding us, brings to the mind sensations of an antagonistic character, our movements become uncertain, from the loss of that power of guidance and control over them which the harmony of the two sensations usually gives. Thus a person unaccustomed to look down heights *feels* insecure at the top of a tower or a precipice, although he *knows* that his body is properly supported; for the void which he sees below him contradicts (so to speak) the tactile sensations by which he is made conscious of the due equilibrium of his body. So, again, any one can walk along a narrow plank which forms part of the floor of a room, or which is elevated but a little above it, without the least difficulty, and even without any consciousness of effort. But let that plank extend across a chasm, the bottom of which is so far removed from the eye that the visual sense gives no assistance; and even those who have braced their nerves against all emotional distraction feel that an effort is requisite to maintain the equilibrium during the passage over it; — that effort being aided by the withdrawal of the eyes from the abyss below, and the fixation of them on a point beyond, which at the same time helps to give steadiness to the movements, and distracts the mind from the sense of its danger. The degree in which the muscular sense is alone sufficient for the guidance of such movements, when the mind has no consciousness of the danger, and when the visual sense neither affords aid nor contributes to distract the attention, is remarkably illustrated by the phenomena of Somnambulism; for the sleep-walker traverses, without the least hesitation, the narrow parapet of a house, and crosses narrow and insecure planks, chambers, roofs, &c., under circumstances that clearly indicate the nature of the guidance by which they are directed (see SLEEP, p. 694). The dependence of our ordinary power of maintaining our equilibrium upon the combination of the guiding sensations derived through the sight and the touch, is further well illustrated, as Mr. Mayo has pointed out *, by what happens to a landsman on first going to sea. "It is long before the passenger acquires his 'sea legs.' At first, as the ship moves, he can hardly keep his feet; the shifting lines of the vessel and surface of the water unsettle his visual stability; the different inclinations of the planks he stands on, his muscular sense. In a short time, he learns to disregard the shifting images and changing motions, or acquires facility in adapting himself (like one on horseback) to the different alterations in the line of direction in his frame." Before this power, however, has been gained, the passenger has usually to experience most distressingly that peculiar feeling of *want of support*, which is consequent upon the pitching and rolling of the ship, but more particularly upon the former. As the part of the vessel on which he is standing, sitting, or lying, *rises* beneath him, there is a comfortable sense of support; but as it sinks, the want of support is most disagreeably felt; and the continual repetition of this sensation gives rise to nausea and vomiting. The tendency is increased by the sight of continually shifting lines and surfaces, which of itself, with many individuals, disposes to the same state; and hence it is that the sickness may often be kept at bay by simply closing the eyes, so as to exclude these objects; whilst, on the other hand, the effort to stand or walk only serves to augment the distress, by increasing the sense of instability. — The giddiness and nausea produced by rapidly turning round, are the results of the same sensations. They are usually excited more through the visual than through the tactile sense; but that the latter is of itself quite sufficient to produce them, is obvious from the fact that they are experienced when the eyes are closed, as well as by blind persons. The feeling of disturbed equilibrium is more persistent than most other sensations; thus when a person has turned round quickly several times in succession, and then suddenly stops, he feels a whirling sensation, which excites a disposition to continued motion in his limbs, and the surrounding objects appear to move before

* Outlines of Physiology, p. 355.

* Loc. cit.

his eyes. But if, as Mr. Wheatstone has pointed out, the person who is turning round holds a large sheet of paper before and near his face, so as to exclude all sight of the room, and fixes his eyes upon a point — a letter, for instance, in the middle of the paper, — when he stops, he finds his head perfectly steady, and the surrounding objects have no apparent motion ; but his legs feel unsteady, as if they continued actually turning round. And it is thus clearly proved that the cause of the giddiness lies in the affection of the senses, and not (as is usually imagined) in disturbed cerebral action.

Sense of Weight. — This is usually derived from a double source; namely, the impression made upon the cutaneous surface by the simple pressure of the body; and the consciousness of the muscular effort employed to resist that pressure. The latter enables us to compare the weights of different bodies much more accurately than the former, which is liable to excite fallacious ideas. The extent of surface, for example, which is in contact with the skin, greatly modifies the estimate of the pressure of a heavy body ; the body feeling lightest when its pressure is distributed over a larger surface, and *vice versâ.* Thus, a truncated cone seems heavier when it rests (without any effort being made to raise or support it) upon its small extremity, than when it rests upon its large extremity on the same part of the surface. At first sight this fact appears altogether antagonistic to the one just stated with regard to the sense of temperature, the impressions on which are more powerful when they are made over a large than over a small surface. But it is to be borne in mind, that in the latter case an absolutely larger amount of calorific influence is exerted, when the large surface is exposed to the action of heat; whilst in the former, the amount of pressure is really the same, whether it be distributed over a larger or a smaller area. The experiments of Weber on the relative information derived from the mere sense of pressure, and from the sense of muscular effort, in the appreciation of weights, are very instructive. He found that if the two hands of the same individual be placed upon cushions, and unequal weights be placed upon the right and left hands respectively, the eyes being kept shut, it will not be possible to say on which hand the heavier weight lies, unless the difference be very considerable; but a comparatively small amount of difference is at once discriminated, when a muscular effort is made to lift the hands from the cushions. This power of comparison is capable of being rendered more exact by practice; so that men accustomed to estimate weights by poising them in their hands, will readily distinguish between two which differ only by one-thirtieth part. It is found that the power of comparison is much greater (as in the estimation of temperature) when the impressions are *successively,* than when they are *simultaneously* made, provided that the interval be not too long. Thus in the comparison of two weights, the greatest nicety is attained by poising the one, and immediately afterwards the other, in the same hand ; but the intervention of a few seconds between the poising of the first and that of the second does not prevent their accurate comparison. The interval may amount to twenty seconds, and yet a just estimate may still be made ; but when it amounts to forty seconds all accuracy is lost. Professor Weber has further ascertained, that, in the estimation of weights by their simple pressure on the surface, the left side and extremities have usually a more acute perception than the right ; for out of fourteen individuals, he found this to be the case in eleven; in two, the contrary was observed ; whilst in one, no difference was perceptible.

Sense of Direction. — The combination of the muscular with the simply tactile sense enables us also to judge in some degree of the *direction* of the pressure. Of this we gain no information whatever from the tactile sense alone, which always suggests the idea that the pressure is made vertically to the surface, when it is not corrected by the sense of muscular effort called forth to antagonise it. The following example, given by Weber, shows how completely involuntary may be this effort, yet how large a share it has in communicating to us the information we derive from an impression, of whose direction we are rendered cognisant. When a hair of the head is pulled, he remarks, we can judge perfectly well of the direction of the traction ; this power of discrimination is not, however, derived (as might at first be supposed) through the sensation originating in the bulb of the hair, but from the sense of the muscular effort which is called forth to antagonise the traction, and to keep the head steady during its continuance. If we prevent these muscles from being called into play, by steadily holding between the hands the head of the person operated on, and if we also prevent the traction from calling forth the muscular action of the scalp, by surrounding the point from which the hair is pulled with a firm pressure by the fingers, we find that the discriminating power is completely lost ; the subject of the experiment being totally unable to distinguish the direction from which the hair is pulled.

It is by this combination, too, that we judge of the rate and direction of the *passive motion* of our bodies, when we have no other means of guidance. If, for example, a person be seated in a carriage, with his eyes closed, and the carriage be suddenly put in motion, the inertia of his body causes it to be thrown in the contrary direction ; and, in order to recover and sustain its equilibrium, a muscular effort is required, which is greater in proportion to the rate of motion. If the motion continue uniform, however, this effort becomes so habitual that he ceases to be conscious of it ; and he only becomes cognisant of the motion by its cessation, the equilibrium of the body being then again disturbed by its inertia, which tends to impel it in the direction in which it was previously moving, so as to require the effort of a contrary set of muscles for the maintenance of the erect position.

Mental Phenomena connected with the Sense. — The interpretation which the mind puts upon the impressions made by external objects upon the tactile organs, is partly the result of intuition, partly of experience. Thus we intuitively refer an impression made upon any part of a sensory nerve in its course, to the peripheral extremities of that nerve, or (as in cases of amputation) to the part from which they should normally arise. So, again, if a part of the body be removed from its usual position and connections (as in the Taliacotian and various other operations of plastic surgery), impressions made upon it continue to be referred to its original seat, so long as it retains any nervous connection with it, and until new connections have been formed with the nerves of the part to which it has been transferred. So, again, when our members are in an unaccustomed position, we still, unless our attention be directed to the fact, interpret impressions made upon them as if they were in their ordinary relation to each other, and may thus be altogether misled: — as in the experiment mentioned by Aristotle, of rolling a pea or other globular body between two fingers of one hand, which are crossed instead of lying parallel, so that the surfaces that are usually most distant are brought into proximity with each other; the sensation then received is that of a distinct convex body opposed to each of these surfaces, so that the single body seems to be double; whereas, if the pea were rolled between the two surfaces which are usually and normally approximated, it is felt but as a single globe. This intuitive reference is obviously analogous to that by which we judge of the relative situations of visual objects, from the direction in which their rays impinge upon the retina, or from the muscular sensations received from the muscles of the orbit.

In a large proportion of other cases, however, our interpretation of our tactile sensations, especially of all those which relate to the configuration, density, &c. of external objects, is based on experience; and those who watch the eagerness with which the infant grasps and examines by its touch every attractive object within its reach, are at no loss to perceive how the experience thus early interwoven (as it were) with the mind, in combination with that derived through the visual sense, comes to supply the place of the congenital intuitions of the lower animals, and to cause the tactile and visual perceptions to be henceforth so indelibly associated, that each is continually suggesting the other. Thus, the notion of *projection*, which we derive through the sight, comes to be associated with that of *solidity*, which we receive through the touch; and the visual notion of *polish* is so closely connected with the tactile notion of *smoothness*, that the one almost necessarily suggests the other. There is abundant evidence, however, that there is no necessary or intuitive connection between the ideas which we derive through these two senses respectively; but that this connection is acquired by the consentaneous exercise of them. Thus, from observations made upon persons born blind, when visual power has been first obtained, it is certain that the notions of *form* previously acquired by the touch do not aid in the visual discrimination or recognition of objects: so that, for example, if any such person had previously learned to distinguish a sphere, a cube, and a pyramid, by the touch, he would not be able to say which was which by looking at them, until he had learned by experience to associate the two classes of perceptions: and, conversely, we cannot but believe that the same result would occur, if a person whose notions of the external world were derived from the sight alone, were suddenly and for the first time to become endowed with the sense of touch.

It is, in fact, no less clear in regard to the sense of touch than it is in regard to vision, that it is not the *sentient organ* (as we are accustomed to term it), but the *mind*, which really perceives; and that all the notions which we derive through this sense with respect to external objects, whether they be of the most general kind or of a more particular nature, are altogether distinct from the sensations themselves. It has been well remarked by Professor Alison, that "one decisive proof of this being the true representation of this part of our mental constitution is obtained by attending to the idea of extension or space, which is undoubtedly formed during the exercise of the sense of touch, but which is no sooner formed than it 'swells in the human mind to infinity,' to which, certainly, no human sensation can bear any resemblance."* So, again, the elementary notion of an external universe as something distinct from the individual *self*, is altogether distinct from the sensations which excites it. All that the mind is conscious of, is a change in the condition of the corporeal organism; and the reference of the source of this change to some external agency is a mental process in which the action of the purely sensorial apparatus has no concern.

It has been thought by some that the notion of an external world depends more upon the sensations received through the touch, than upon those of any other kind. But there does not seem to the author to be any reason for considering that simply tactile impressions are more necessarily or intuitively recognised as proceeding from an external source than are the visual, olfactive, auditory, or gustative. But, as already shown, it is from the muscular sense that we derive the idea of *force*, involving resistance to our own voluntary efforts; and it would seem to the writer to be on this notion that our belief in the existence of an universe external to ourselves most securely rests.

The active co-operation of the mind is required, not only for the formation of the

* Outlines of Physiology, 3rd ed. p. 290.

notions so immediately springing from sensations as to be often confounded with them, but also for the reception of the sensory impressions themselves. Until, in fact, the mind has been affected by these impressions, no sensation can be said to exist; and that of which the mind takes cognisance is not the external object but the impression produced by it, and not the direct or immediate impression produced by it upon the organ which first receives it, but the change in the sensorium consequent upon this. (See SENSATION.) That this is the true account of the process is now universally admitted both by the psychologist and the physiologist; and it is placed beyond all reasonable question by the occurrence of those *subjective* sensations, which, until their indications are corrected by experience, may suggest the idea of an external source, with such vividness and definiteness, that the objective *unreality* can scarcely be credited. In some instances the excitement of these subjective sensations appears due to the occurrence of a change in the part in which they are felt, which simulates that which would be produced by an external impression; as in the case of the sensation of extreme heat, which is often experienced in inflammation to a degree far beyond that which the actual exaltation of temperature would account for; and the pain, of various kinds, often resembling that inflicted by external injuries, which is the result of morbid changes in the part to which it is referred. But in other cases they are clearly referable to changes taking place in the course of the nerve-trunk to the sensorium, which simulate those which would naturally occur in it when it is the conductor of an external impression; of this several examples have already been given. Or, again, they may be due to a change purely sensorial; as in the various cases of "radiation of sensations" elsewhere alluded to (see SENSATION); or, as in the sensations of nausea, of shuddering, of tickling, of pain, &c., which are frequently excited by changes purely mental. The degree of intensity, again, with which actual sensations are felt, depends as much upon the state of the mind as upon that of the corporeal organism. Thus, if we experience a slight itching in the skin, and direct our thoughts to it, we are speedily annoyed by its increase; whilst, if we steadily fix our thoughts upon some other object, we are soon unconscious of the irritation. On the other hand, the complete absorption of the mind in some train of thought which engrosses its attention, may render the individual unconscious of impressions that would ordinarily induce severe pain. This is remarkably seen in cases of natural and artificial somnambulism (see SLEEP); and it is probable that in many of the cases in which insane patients have inflicted severe wounds upon themselves, without appearing to feel pain, the cause of the immunity from suffering is to be found in the entire possession which some dominant feeling or idea has of their consciousness, so that they are not cognizant of any external impressions but such as harmonize with it. Even in ordinary cases, it is well known that a severe injury suddenly inflicted, is much less felt *at the moment* than a far slighter injury of which the mind has been in expectation; thus, a limb has been carried away by a cannon-ball, or the chest traversed by a bullet, with far less consciousness of pain than is produced by the trivial incision made in ordinary venesection.

Improveability of the Sense of Touch. — The mental participation in the phenomena of tactile sensation is further rendered obvious by the improvement in discriminating power which results from continual *attention* to its indications. Of this we have examples in the case of certain artisans, whose employments require them to cultivate their tactile discrimination; thus, the female silk-throwsters of Bengal are said to be able to distinguish by the touch alone *twenty* different degrees of fineness in the unwound cocoons, which are sorted accordingly; and the Indian muslin-weaver contrives, by the delicacy of his touch, to make the finest cambric in a loom of such simple construction, that European fingers could at best propose to make a piece of canvas in it. The improvement in tactile discrimination is more especially seen, however, in those individuals whose dependence upon it is increased by the loss or deficiency of other senses; and especially by blindness, congenital or acquired. Whilst it is doubtless to be attributed, in great part, to the concentration of the attention and of the powers of recollection and comparison upon the sensations which are brought (as it were) to the mind, it may not seem altogether improbable that the improvement may in part depend upon an increased development of the tactile organs themselves; resulting from that augmented nutrition which would be the natural consequence of the frequent use of them, and of the increased flow of blood that seems to take place towards any part on which the attention is continually fixed. Certain it is, that many blind persons can not merely obtain as definite and accurate conceptions of the form, surface, &c., of objects over which they rapidly pass their hands, as others could only derive from the long and painstaking examination of them by their tactile organs; but they can discriminate minute differences, of which those who have not specially cultivated this faculty remain quite unconscious, even when their attention is pointedly directed to their discovery. The process by which the blind learn to read from books printed in an elevated type for their special use, affords an interesting illustration of the nature of the improveability of the proper sense of touch. On first making the attempt, the learner needs to use a large type; and even although (to a person who has previously enjoyed his sight), the *visual* form of each letter may be well known, yet considerable experience is required for the ready recognition of the *tactile* form of each separate letter. After this step has been gained, the individual becomes able, by a further period of diligent application, to recognise the combination of letters in syllables and words, without forming a separate idea of each letter, just as we see to take place in the child learning to read by eyesight; and the pupil in time acquires the power of reading line after line, by passing the point of the finger consecutively over each, with considerable rapidity. Now when this power has once been thoroughly acquired, it is found that the size of the type may be gradually diminished, so that at last it may be reduced to one but little larger than that of an ordinary folio Bible, which is read at least as rapidly as the words can be spoken.* As an instance of the readiness and nicety of discrimination which is frequently acquired by those who are chiefly dependent upon this sense for their knowledge of the outward world, we may advert to the well-known case of Laura Bridgman; who, though destitute of sight, hearing, and smell, is able to recognise individuals with whom she has once been well acquainted, by feeling their hands, even after a long distance of time. It is related of Carolan, the celebrated blind Irish bard, that on accidentally grasping, at an interval of some years, the hand of a female to whom he had been formerly attached, he at once exclaimed, with strong emotion, "This is the hand of Bridget Cruise." A lady, who became blind, and soon afterwards deaf and dumb, in consequence of an attack of confluent small-pox, and whose case is recorded in the Annual Register for 1758, seems to have very speedily acquired a remarkable exaltation of the sensibility she retained. Like James Mitchell (see SMELL, p. 702.), she could distinguish strangers from acquaintance by the smell; but she required the further help of the touch to distinguish one friend from another. "When they came in, they used to present their hands to her as a means for making themselves known. The form and the warmth of the hand generally furnished the differences which she distinguished; but sometimes she would span the wrist and measure the fingers. A lady with whom she was well acquainted, coming in upon a very hot day after having walked a mile, presented her hand as usual; she examined it longer than ordinary, and seemed to doubt to whom it belonged; but at length she said,—'I think it is Mrs. M.; but she is warmer to-day than I ever felt her before.'"†

Of this lady it is positively affirmed that she was able to distinguish colours by the touch. "A lady, who was nearly related to the sufferer, having an apron on, which according to the fashion of the time, was embroidered with silk of different colours, asked her if she could tell her what colour it was; and after applying her fingers attentively to the figures of the embroidery, she replied that it was red, blue, and green; but whether there were other colours in the apron, the writer of the account does not remember. The same lady having a pink ribbon on her head, and being desirous still further to satisfy her curiosity and her doubts, asked her what colour that was? After feeling it for some time, her cousin answered that it was a pink colour. This answer was the more surprising, as it showed that she was not only capable of distinguishing different colours, but different shades of the same colour."* It is probable that in this and similar cases, the difference of *hue* is indicated by some difference of *surface*, which becomes appreciable to a refined touch. Of course, it can only be to a person who has once enjoyed sight, and who can therefore form ideas of colour, that such ideas could be suggested by the sense of touch; and a new set of associations must be formed by habit between the *tactile* qualities of the surface, and the visual conception called up by its designation. Those who have been born blind must be utterly incapable of forming any such conceptions, and distinctions of colour can be to them nothing more than names; yet even such have been able to discriminate by the touch between stuffs of different hues, which were similar in other respects. That such a power should be attained seems the less difficult of belief, when it is borne in mind that all colour depends upon the molecular arrangement of the particles of the surfaces of bodies; so that there is no great improbability — much less an impossibility — in the asserted discrimination of these by a touch rendered delicate by constant practice, and by the habit of attending to its minutest indications. It is well known that Dr. Saunderson, the celebrated blind professor of mathematics at Cambridge, not only acquired a very accurate knowledge of medals, but could even distinguish genuine medals from imitations, more certainly than most connoisseurs in full possession of their senses; and this power must have depended on peculiarities of their surface, too minute to be appreciated by an ordinary touch, and not distinguished by the sight.

Not only does the sense of touch, in its simplest form, undergo this remarkable exaltation, but also the *muscular sense*, which is employed in combination with it in the acquirement of information respecting the forms, dimensions, distances, &c. of objects. Of this, the case of the lady just cited affords an apt illustration: "To amuse herself in the mournful solitude and darkness to which she had

* It is worthy of remark, that, when the idea of teaching the blind to read from raised characters was first being carried into practice, it was thought requisite by many to adopt a new alphabet of simpler forms, instead of the ordinary letters, in order that they might be more readily discriminated. This plan, however, was subject to the disadvantage that the teacher as well as the pupil was compelled to learn this new alphabet; and as it was soon found that the ordinary Roman capitals, reduced to their simplest forms, could be discriminated by the blind with very little more trouble than the best set of new signs that could be devised, the idea of a special alphabet for their use has been given up.

† "Lost Senses," vol. ii. p. 81.

* Op. cit. p. 79.

been reduced, the sufferer took to working with her needle; and it is remarked that her needlework was uncommonly neat and exact. Among many other pieces of needlework preserved in her family, was a pincushion which could scarcely be equalled. She used also sometimes to write; and her writing was executed with the same neatness and precision as her needlework; the characters were very pretty, the lines were all even, and the letters placed at equal distances from each other: — but the most extraordinary circumstance was, that she could by some means discover where a letter or a word had been omitted, and would place the caret under and the word over, in the right place."* This fact is obviously analogous to those formerly related, in reference to the exaltation of the muscular sense in the state of somnambulism. (See SLEEP, p. 694.) It is by the accurate estimates which they are thus enabled to form, that we find the blind able to learn various handicraft arts, performance on musical instruments, &c. &c., which they practice with great success; cabinet-making, turning, and even watch-making, seem to be within the capacity of such as have a mechanical turn; but the greatest perfection of this sense is shown by those who have succeeded in modelling and sculpture. Of these, Giovanni Gonelli, sometimes called Gambasia, from the place of his birth, deserves special mention. He lost his sight at the age of twenty, and remained for ten years in that state, ignorant of the very elements of sculpture. But, on a sudden, the desire of making a statue came upon him; and having handled in every way a marble figure representing Cosmo de Medici, he formed one of clay so extremely like, that it astonished all who saw it. His talent for statuary soon developed itself to such a degree, that the Grand Duke Ferdinand of Tuscany sent him to Rome to model a statue of Pope Urban VIII., which he also rendered a very striking likeness of the original. He afterwards executed many others with equal success; amongst these, a marble statue of our Charles I. It is related that the Duke of Bracciano, who had seen him at work, doubted much that he was completely blind, — and in order to set the matter at rest, he caused the artist to model his head in a dark cellar. It proved a striking likeness. Some, however, objecting that the duke's beard, which was of patriarchal amplitude, had made the operation of producing a seeming likeness too easy, the artist offered to model one of the duke's daughters, which he accordingly did; and this also proved an admirable likeness. Dr. Guillée, who details the preceding case in his "Essai sur l'Instruction des Aveugles," mentions also the more recent case of M. Buret, whom he calls "one of the most able sculptors of the academy;" who became blind at the age of twenty-five, but was not thereby deterred from pursuing with much success, the course of life which he had previously chosen. It is easy to be conceived that a blind man might thus model or chisel accurately under the guidance of his touch, so far as mere *form* is concerned; but it has been thought difficult to understand how he could thus discriminate and embody that *expression*, which has been supposed to be intangible* When it is remembered, however, that expression must at last depend upon niceties of form, and can only be imitated by the sculptor who is under the guidance of his sight, by a minute attention to these niceties, the difficulty altogether disappears. The blind sculptor cannot form an idea of the expression of his model, as seen by the eyes of others; but he may reproduce that expression with complete success, by perfectly imitating the form which exhibits it; just as he may study and understand the laws of optics, without having ever seen the faintest ray of light. The study of natural history might have been supposed to be beyond the reach of the blind, in consequence of the difficulty of distinguishing specimens by the touch alone; yet there have been examples of complete success in this pursuit. Thus of John Gough it is related, that "from an early age he showed a very decided taste for zoology; and in time he began to enlarge his knowledge of organic bodies by extending his researches from the animal to the vegetable kingdom. To botanical pursuits all the time he could spare from the necessary studies of the school was most assiduously devoted; and as his ardour in cultivating this branch of science was never relaxed, he soon conquered most of the difficulties which the want of sight opposed to the gratification of this taste, and was eventually able to discriminate and arrange with great accuracy the plants that came under his notice. His usual method of examining a plant was by applying the tip of his tongue to its several parts. Ordinary plants he could easily and readily distinguish by the touch of his fingers. To evince the power of discrimination and strength of memory, which could alone have enabled him to take an interest in this pursuit, it is mentioned, that towards the end of his life a rare plant was put into his hands, which he very soon called by its name, observing that he had never met with more than one specimen of it, and that was fifty

* Op. cit. p. 81. It is worthy of remark, that in consequence of the strangeness of these facts to those who observed them, it was long doubted whether some faint remains of sight or hearing did not exist. Many experiments were tried to settle this matter; but in this great caution was necessary; for some of these being accidentally discovered, she fell into violent convulsions, — these being apparently induced by the mental agitation she experienced at the thought of being suspected of insincerity, or of being supposed capable of acting so wicked a part, as to feign such infirmities. Sir Hans Sloane, who attended this patient, long entertained doubts respecting the facts related of her; but having been permitted to satisfy himself by whatever experiments he thought proper, he at length declared his conviction that she was *totally* blind, deaf, and dumb.

* "Lost Senses," vol. ii. p. 224.

years ago."* A case of the same kind has been long under the writer's observation; the subject of it being a gentleman who became blind from amaurosis soon after the age of twenty. His attention having been directed to geology and conchology, he gradually acquired a very complete knowledge of shells both recent and fossil; being not only able to recognise every one of the numerous specimens in his own cabinet, but also to mention the nearest alliances of a shell previously unknown to him. He has occupied himself, moreover, in freeing his fossil shells from their matrix, with a hammer and chisel, knife, &c.; and has frequently done this with a perfection that could scarcely be surpassed, rarely injuring the specimen with his tools, and generally clearing it completely from its incrustation, where this was practicable. In this way he has succeeded in forming a very valuable collection of the fossils of the interesting locality in which he resides.

A similar exaltation may manifest itself, under the like circumstances, in the *general tactile sensibility*, both of the surface and interior of the body, especially as affected by the vibrations transmitted through solid substances; whereby a deficiency in the sense of hearing is in some degree supplied. Thus the visitor to a school for the deaf and dumb remarks with surprise that a slight rap given by the master on the table or floor is sufficient to excite the attention of the pupils; and finds on examination that this is not *heard*, but is *felt* by them. A minute account of his personal experience on this head is given by Dr. Kitto; and as it involves several interesting physiological considerations, the principal facts mentioned by him will be here brought under the notice of the reader. — "In the state of entire deafness," he remarks, "a peculiar susceptibility of the whole frame to *tangible percussions* supplies the only intimations which have the slightest approximation to those which hearing affords. I was about to call this a peculiar susceptibility of the sense of touch; but this would unduly limit a kind of vibration, which, in certain of its developments, seems to pervade the whole frame, to the very bones and marrow. I do not at all imagine that there is in this anything essentially different from that which is experienced by those who are in possession of their hearing; but it would seem that the absence of that sense concentrates the attention more exclusively upon the sensation which is through this medium obtained; and the intimation of which, being no longer checked and verified by the information of higher organs, assume an importance which does not naturally belong to them." This sense of percussion is but little excited in the human body by the vibrations of air; obviously because there is no expanded surface adapted to receive their influence. Thus Dr. Kitto mentions that the loudest thunder makes no impression upon him, unless it shakes the house in which he is; in which case it communicates a sensation resembling that produced by the removal of a piece of furniture in an adjoining room.* In like manner, he is utterly unconscious alike of the *sound* of bells, and of the vibration produced by their percussion, unless the latter be propagated through solid bodies, as when he places himself in direct contact with a tower in which a powerful peal is being rung. "I remember," he says, "that once when I was showing a young friend from the country over St. Paul's, we happened to be up examining the great clock, at the very time it began to strike. The sensation which this occasioned was that of very heavy blows upon the fabric in which I stood, communicated to my feet by contact with the floor, and by the feet diffused over the whole body. So," he continues, "guns — even powerful cannon — make no impression upon this sense, unless I happen to be very near when they are fired; in that case, I can compare the effect to nothing better than the sensation produced by a heavy blow upon the head from a fist covered with a boxing glove. This effect could only be produced by the *tangible* percussion of the air, and by the percussion upon the ground transmitted by the feet." So, again, Dr. Kitto states that he is not conscious of even a very loud knock at the door of the room in which he is, unless the door be in such connection with the floor that the percussion is communicated through the latter, or unless he be himself in contact with some part of the wall to which it is hung. But, on the other hand, he states, — "The drawing of furniture, as tables and sofas, over the floor above or below me, the shutting of doors, and the feet of children at play, distress me far more than the same causes would do if I were in actual possession of my hearing. By being to me unattended by any circumstances or preliminaries, they startle dreadfully; and by the vibration being diffused from the feet over the whole body, they shake the whole nervous system, in a way which even long use has not enabled me to bear. The moving of a table is to me more than to the reader would be the combined noise and vibration of a mail coach drawn over a wooden floor; the feet of children, like the tramp of horses upon the same floor; and the shutting of a door like a thunder-clap, shaking the very house. It is by having once heard, that I am enabled to make such comparisons as these, for the illustration of a sensation which one who has never heard, and one who is not deaf, would be alike unable to describe." The fact that the shutting of a door is felt with painful distinctness (as Dr. Kitto elsewhere mentions), even when upon a different floor, whilst the loudest ordinary knocking at the same door is not perceived, very curiously

* "Lost Senses," vol. ii. p. 215.

* The writer of this article, residing near a railway tunnel, has frequently noticed that the emergence of a train is indicated by the succussion of the windows of his house, *before* it becomes audible.

illustrates the necessity for the transmission of the vibrations along a solid medium. "The valve of the door on which the percussion is made by *knocking*, is a detached frame of wood hung upon hinges, and the vibration is therefore comparatively isolated and not propagated throughout the frame of the house, as is the case when, in *shutting* the door, the valve itself strikes the door-post, which is identified with the framework of the building." In illustration of the acuteness of this sense in his own person, Dr. Kitto states that the lightest footfall upon the same floor is quite sufficient to attract his attention, or even to arouse him from sleep. "If any small article," he continues, "such as a thimble, a pencil, a penknife, or even a more minute object, falls from the table to the floor, I am often aware of it, even when other persons sitting at the same table have not been apprised of it by the ear. The greater the number of my points of contact with the floor, the stronger are the impressions I receive: hence they are more vivid and distinct when I sit than when I stand; because, in the former case, not only my own two legs, but the four legs of my chair, are concerned in conveying the percussion to my sensorium. And when the chair itself on which I am seated has been subject to the percussion, the sensation is such as baffles description. For instance, a few days since, when I was seated with the back of my chair facing a chiffonière, the door of this receptacle was opened by some one, and swung back so as to touch my chair. The touch could not but have been slight, but to me the concussion was dreadful, and almost made me scream with the surprise and pain, the sensation being very similar to that which a heavy person feels on touching the ground, when he has jumped from a higher place than he ought. Even this concussion, to me so violent and distressing, had not been noticed by any one in the room but myself. * * * If these perceptions are so acute in carpeted rooms, it will be easily understood by how much more intense they become upon a naked wooden floor. The sensation then amounts to torture — as every movement or concussion, in any part of the room, then comes with an intensity of effect, far more than proportioned to the difference in the impression which would, under the same circumstances, be produced upon the auditory sense."

It is interesting to remark that, notwithstanding this acuteness of the sense in question, it does not seem to convey (in Dr. K.'s case at least) any information of the *direction* or *distance* of the percussions, except such as is afforded by their relative intensity. Thus he says; — "I am unable to determine from the information of the sensation itself, whether it has occurred upon the floor above, or in that below me, or in the passage or room adjoining that in which I may be at the time. I am not aware that the impression is more distinct from the floor above than from that below; but it certainly is more distinct in another room of the same floor, than from either the one above or below; whence I am much in the habit of referring to the next room the percussions which make the strongest impression on me. In this I am not seldom mistaken. * * * The information is equally defective, even in the very room I may happen to occupy. If a book or other object falls in any part of the room, the sensation is painfully distinct, the percussion being upon the very boards on which I stand; but even in this case, I am at a loss for the quarter in which the circumstance has occurred, and generally look for it in the wrong direction, and have to scan the whole room with my eye before I can make it out." It is probable that the want of power to estimate direction arises from the circumstance that the communication of the percussions takes place, in this and similar cases, through the *same* channel (the floor) to the *same* parts of the solid mass of the body, through which the vibrations immediately spread in every direction. It can easily be conceived that if the percussions were transmitted through a liquid medium, its vibrations, being propagated in a more determinate direction, might affect one or another part of the surface in such a manner as to suggest the direction of their source; and that in this mode aquatic animals endowed with a nervous apparatus at their surface, specially adapted to be impressed by such vibrations, might communicate with each other through great distances. This appears to be the case with regard to the Spermaceti Whale, and probably others of the Cetacea. It has been observed by the whale-fishers, that when a straggler from a "school" is attacked, even at a distance of several miles from it, a number of its fellows bear down to its assistance, in an almost incredibly short space of time. It can scarcely be doubted that this communication must be made through the medium of the vibrations of the water, excited by the struggles of the animal, or perhaps by some peculiar instinctive movements especially adapted for this purpose, and propagated through the liquid medium to the large cutaneous surface of the distant whales. And this idea is confirmed by the fact, that the nerves which proceed to the surface of the body pass through the layers of blubber (which form the inner part of the true skin) with scarcely any division, and then spread out into a network of extreme minuteness as soon as they approach the exterior of the integument. The expanse of such a network over a thick layer of elastic tissue, whose meshes are distended with oleaginous fluid, obviously affords a condition peculiarly favourable to the reception of impressions originating in percussion.

After the details which have been given in proof of the degree of exaltation of which the general tactile sensibility is capable in the human subject, we shall have less difficulty in understanding that even the vibrations of *air*, excited by percussion, may become the chief means of guidance to animals possessed of a special apparatus for taking cognisance of them. Such appears to be the case in the *Bat* tribe, and especially in those species whose habits are most exclusively nocturnal, and whose dwellings admit the smallest quantity of light. "The whole surface of their wings, on both sides, may be considered as an enormously-expanded organ of touch, of the most exquisite sensibility to the peculiar sensation for which it is intended; and it is, therefore, by the varied modifications of the impulsion of the atmosphere upon this surface, that the knowledge of the propinquity of foreign bodies is communicated."* It would not seem improbable, however, that the remarkable cutaneous expansions with which the nose and ear are furnished in many bats, are subservient to this function. The enormous extension of the external ear may doubtless augment the intensity of the sense of hearing; but it is scarcely accordant with our knowledge of the conditions under which the sense of smell is exercised, to suppose that the extraordinary "nose-leaf" of the *Rhinolophidæ* should be in any great degree subservient to olfactive purposes. The bats of this group (to which belong the greater and lesser horse-shoe bats of our own country) "are more completely lucifugous and retired in their habits than any others; they are found in the darkest penetralia of caverns, and other places where there is not even the imperfect light which the other genera of bats enjoy." † Some approach to this power of guidance, derived either from the impressions made by the air upon the cutaneous surface, or from the radiation of heat, is occasionally seen in blind persons; who can thus distinguish by the hands, and even by the face, the proximity of solid bodies (as in approaching a wall, a door, or a piece of furniture) without actually touching them.

The *sense of temperature*, also, appears to be capable of considerable improvement, when its indications are habitually and discriminatingly attended to, or when the mind is intensely and exclusively fixed upon them. Thus it is related of Dr. Saunderson, that when some of his pupils were taking the sun's altitude, he was able to tell, by the slight alteration in the temperature of the air, when very light clouds were passing over the sun's disk.

Morbid Conditions of the Sense of Touch.

Like most other vital functions, the sense of touch may become disordered in the way of *deficiency*, *excess*, or *depravation*.

The state of complete deficiency is known as *Anæsthesia;* a term which, strictly speaking, designates the absence of *all* sensation, but which is more commonly employed as referring to the sense of touch alone. This state, which may be either general or local, may arise from an interruption in the functional activity of any part of the nervous apparatus concerned in the reception of sensory impressions; and thus may be due to causes acting either (1) at the peripheral origins of the sensory nerves, or (2) on the nerves in their course, or (3) on the sensorial centres; as well as to such as act on the whole nervous system at once. The causes which act at the peripheral origins of the nerves may be such as affect either the nerves themselves, the capillary circulation, or both. Of the first we have a typical example in the "anæsthetic agents," ether, chloroform, &c.; the application of whose vapour for any length of time to the cutaneous surface, entirely suspends its power of receiving sensory impressions; and that this results from the direct action of the substances on the peripheral nervous expansion, appears from the fact of the suspension being precisely limited to the part to which the vapour is applied. But anæsthesia may be induced, also, by the stagnation of the capillary circulation in a part, without any more direct affection of its nervous endowments; as we see when the main artery of a limb has been tied, previously to the re-establishment of the supply of blood by the collateral circulation, or when the flow of blood through it has been impeded by temporary pressure. It is probable that cold operates in producing local anæsthesia in both these modes; namely, by its direct sedative action upon the peripheral nerves; and by the stagnation which it produces in the capillary circulation. That the local anæsthesia, which is a not unfrequent result of the presence of poisonous substances in the blood, is due to the special action of these substances upon the peripheral nerves of the particular locality, would not seem an improbable supposition; when it is remembered how frequently poisons of various kinds single out some particular part of a structure apparently homogeneous, for the production of their peculiar effects,—lead, for example, in whatever way introduced into the system, acting first on the muscular fibres of the alimentary canal, and afterwards most commonly on the extensor muscles of the forearm, in which its presence has been detected by chemical analysis.

Of the anæsthesia induced by causes acting upon the sensory nerves in their course from the periphery to the centre, our most frequent examples are those in which it is produced by *pressure* on these trunks, whereby the conveyance of the sensory impressions to the encephalon is effectually checked. Anæsthesia may also arise, however, from diseased conditions of these trunks, brought about by perverted nutrition; and there is a form of paraplegia, in which the lesion of sensibility (which is more completely lost than the motor power) appears to commence in the peripheral expansions of the nerves, and to extend along the trunks to the central organs.* This is

* See Cheiroptera, vol. i. p. 599.

† Loc. cit.

* Graves's Clinical Medicine, vol. i. p. 503.

usually referrible, in the first place, to the influence of cold and damp; and it is especially liable to occur in persons of a rheumatic or gouty diathesis. That even the sedative influence of cold may be propagated along the nerve-trunks, and that its anæsthetic effect is not due to its peripheral influence alone, appears from the circumstance remarked by Dr. Graves (loc. cit.), that the paralysis induced by handling snow, or by immersing the hands in freezing mixtures for some little time, is not confined to the hands and fingers, but extends to the muscles and surface of the fore-arms. And it was also remarked by the same eminent physician, that in a case in which the inside of the ring finger had been wounded by a blunt needle, and a partial anæsthesia induced, the same effect was perceived in the little finger (alike supplied by the ulnar nerve), obviously through the extension of the paralysing influence towards the centre, so as to affect the trunk higher up than the point at which its branch to the little finger was given off. Dr. Graves further cites, as an example of anæsthesia having its seat in disordered nutrition of the peripheral nerves, and gradually advancing along their trunks towards the centres, the curious *Epidémie de Paris*, which occurred in the spring and summer of 1828. "It began (frequently in persons of good constitution) with sensations of pricking and severe pain in the integuments of the hands and feet, accompanied by so acute a degree of sensibility, that the patients could not bear these parts to be touched by the bed-clothes. After some time, a few days, or even a few hours, a diminution, or even abolition of sensation took place in the affected members; they became incapable of distinguishing the shape, texture, or temperature of bodies, the power of motion declined, and finally they were observed to become altogether paralytic. The injury was not confined to the hands and feet alone, but, advancing with progressive pace, extended over the whole of both extremities. Persons lay in bed powerless and helpless, and continued in this state for weeks and months. Every remedy which the ingenuity of the French practitioners could suggest was tried, and proved ineffectual. In some, the stomach and bowels were deranged, and this affection terminated in a bad state of health, and even in death; in others, the vital organs, cerebral, respiratory, and digestive, were in the same state as before their illness, and their appetites were good, but still they remained paralytics. At last, at some period of the disease, motion and sensation gradually returned, and a recovery generally took place, although, in some instances, the paralysis was very capricious, vanishing and again re-appearing. In the fatal cases, no evidence could be obtained, from the most diligent search, of any lesion, functional or organic, in the brain, cerebellum, or spinal marrow."* These phenomena are scarcely explicable on any other hypothesis than that of some general cause (probably a morbid matter circulating in the blood) affecting the nutrition and functional activity of the nerve-trunks, rather than of their centres.

* Op. Cit. p. 504.

That anæsthesia may proceed from various causes whose operation is limited to the sensorial centres, is a matter of every-day experience. It is, however, where they have suffered from some obvious lesion of a comparatively restricted character, that the proof of this is most complete; for although there is strong ground for believing that the ordinary operation of anæsthetic agents and narcotic poisons is confined to the cerebrum and sensorium, yet we could not positively affirm such to be the case, since, when taken into the blood, they *may* act not only on the sensorial centres, but on the entire nervous system. All the phemomena of narcoctic poisoning, however, indicate that opium, alcohol, &c., *single out* the cerebrum and sensory ganglia for their special action, just as strychnia singles out the spinal cord; the suspension of the functional activity of the former being usually complete, before there is the slightest affection of the latter. That a failure of the circulation in the encephalon produces complete and universal anæsthesia while it lasts, was fully proved by Sir A. Cooper's well-known experiment; and it seems probable that many of the structural lesions which manifest themselves in paralysis of motion and sensation produce this suspension of functional power in parts not themselves affected by disease, chiefly in virtue of the derangement of the intra-cranial circulation which they invole.

There is one of the phenomena of the anæsthesia produced by the accidental or intentional introduction of poisonous substances into the blood, which seems deserving of more special notice; viz., the suspension of the power of receiving *painful* impressions, without the obliteration of the ordinary tactile sensibility. This is a frequent result of the exhibition of ether and chloroform; and does not seem to depend upon a mere blunting of the ordinary sensibility. It has been especially noticed, also, in cases of lead poisoning, in which state it seems to be more frequent than complete anæsthesia. According to M. Beau, the insensibility to pain, which he terms *analgesia*, may be observed in a large proportion of cases of "saturnine intoxication." "We must not confine ourselves," he remarks, "to asking the patient whether he feels, but limit our question to the sensation of *pain*. Parts which are thus insensible to pain are so also to *tickling*. This form of anæsthesia may affect the entire surface, being, however, most remarkable in the extremities, and especially the upper ones. It may extend even to the mucous membranes, and especially those which are normally endowed with great sensibility, — as the uvula, isthmus faucium, nares, or conjunctiva, — any of which parts may be tickled without the usual consequences, the patient still being quite conscious of the mere contact."*

Reference has been already made to the influence of the *attention* on the acuteness of sensations; and to the slight degree in which they are felt, when the mind is completely engrossed in some other feeling or idea. This is sometimes seen in spontaneous reverie; and there are individuals who can exert such a power of mental abstraction, as voluntarily to concentrate their attention on some external object, or internal idea, so as to escape all suffering from a severe operation. This, however, is much better seen in some of those cases of somnambulism (see SLEEP) in which the mind is completely under the guidance of the *suggestions* received from without, its whole spontaneous directing power being suspended. For it is frequently possible, in such cases, to withdraw the patient's attention from any part of the body, to such an extent that the anæsthesia is complete as regards that part, whilst every other portion enjoys the ordinary sensibility. Thus a temporary loss of sensation on the whole of one side may be induced, or a single limb may be rendered anæsthetic; and the sensibility of the parts may be instantaneously restored, merely by directing the patient's attention towards them.

With regard to *hyperæsthesia*, or increased sensibility, we have much less definite information. There can be no doubt, however, that it, too, may proceed from changes either in the periphery, or in the central organs, and perhaps also from an alteration in the trunks of the nerves in their course. The acute sensibility of an inflamed or irritated part is an example of the first of these conditions; and the extraordinary exaltation of sensibility in the incipient stage of phrenitis may serve as an illustration of the second. In some cases the entire nervous system would seem to partake of this undue excitability; this we especially see in hysterical subjects, in whom the slightest contact frequently occasions intense suffering, so that even the mere pointing of a finger at any part of the body will cause a scream of alarm. The sufferings of such persons are not rightly designated as *imaginary;* they are as *real* to them as are those proceeding from far more serious causes to persons of less excitable temperament. The fault partly lies in the habitual attention which they pay to the most trivial feelings; but in part also, it may be surmised, to an abnormal state of nutrition of the entire nervous system,—both centres and trunks,—from depravation of the blood. This view harmonizes well with the fact just now stated, that in the *Epidémie de Paris*, a temporary hyperæsthesia (afterwards giving place to anæsthesia) was commonly among the earliest symptoms. And it is not a little curious that in the remarkable series of cases of lead-poisoning which recently occurred in the ex-royal family of France, during their residence at Claremont, the same symptom presented itself, and was in some instances the only symptom which indicated the morbid contamination of the blood.* In most cases of this form of hyperæsthesia, the exaltation of sensibility seems confined to the surface, being much more excited by a slight touch than by hard pressure; and this difference will frequently serve to distinguish the "hysterical" tenderness from that of inflammation, in which the pain is augmented the more severe the pressure. The writer has had opportunities of noticing an extreme sensitiveness to changes of temperature in certain cases of somnambulism, both natural and artificial; and he believes that this fact affords a ready solution of various marvels which have been narrated touching the power of "mesmerized" subjects to distinguish a piece of money which had been held in the mesmerizer's hands, or a glass of water in which his finger had been immersed.

It has recently been proposed to apply Prof. Weber's method of estimating the relative acuteness of the tactile sense in different parts of the body, to the determination of the degree of anæsthesia or of hyperæsthesia, in patients affected with these disorders. Thus it was found by M. Brown-Séquard that in one case of nearly complete anæsthesia of the lower extremities, the patient only felt a single impression on the skin of his legs, when the points of the compasses were from 10 to 20 centim. apart; the normal "limit of confusion" for this portion of the surface being from 3 to 5 centim. In another case of slighter anæsthesia, the "limit of confusion" in the same part was from 9 to 15 centim. And in a third case of very slight anæsthesia, it was from 6 to 7 centim. In a case of hyperæsthesia, on the other hand, which accompanied paralysis of the motor power, the patient could perceive the distinctness of the two points on the foot, when they were separated to the distance of only 5 millim., although the normal "limit of confusion" in that part was from 25 to 30 millim. The sensibility to pain, in this case, was as much exaggerated as was the tactile sensibility.

Of the *depravation* of tactile sensibility, manifested in a variety of morbid phenomena,—such as the sense of heat or even of burning (without any real elevation of temperature), of formication, of tickling, of itching, &c.,—it must suffice here to remark, that this, like the preceding affections, may be due to causes acting on the peripheral nerves, or on the nervous centres, or on the connecting trunks. Of the latter we have a good example in the formication which generally succeeds complete anæsthesia, when a nerve has been pressed upon for a time, and the pressure is then removed.

W. B. Carpenter.

* Archives Générales, tom. xvi. pp. 5—24.

* See Dr. Gueneau de Mussy's Cases of Poisoning by Lead at Claremont, in Dublin Quarterly Medical Journal, May, 1849.

TUNICATA. (*Tuniciers*, Fr.; *Nackt-Muscheler* and *See-Scheiden*, Germ.) — The *Tunicata* are molluscous animals, having no calcified shell, but a more or less coriaceous envelope or *tunic*, whence their name. This external coat or *test* is either bag-shaped and provided with two apertures, or is tube-shaped and open at the ends. They have no distinct head, and no organs serving as arms or feet; they are provided with a muscular and a nervous system; and with well-defined organs of respiration, digestion, circulation, and generation.

They are exclusively marine, and are widely spread from the arctic to the tropical seas. Sessile or foot-stalked on the rock, or incrusting seaweed and other bodies, their external form is seldom of graceful contour; yet the arrangement of the individuals in the compound masses often exhibits curious and elegant designs. The floating forms, however, with their lengthened, sinuous chain, or tapering tubes, pellucid, rainbow-tinted, or, by night, brightly phosphorescent, are surpassed by no terrestrial object. The other, fixed, forms, not altogether destitute of elegance of colour in the northern seas, become in warmer climates more and more rich in variegated hues, and in the tropics are amongst the most resplendent living gems of ocean's parterres.

The earliest notice of the *tunicate* animals is made by Aristotle, who gives a very correct account of the anatomical and zoological characters of a simple Ascidian, which he calls Τεθυον.* They, however, attracted no further notice until comparatively late times. Rondelet † gives indifferent figures and descriptions. Gesner and Aldrovandus, uniting Rondelet's *Tethya* with those given by Belon ‡, which are *Alcyonia*, were among the first who gave rise to the confusion that long existed in the history of these animals. Linnæus in the 4th edition of his Systema Naturæ placed a *Tethyum* in his system, under the appellation of *Tethys*; he pointed out at the same time that the animal of bivalve Molluscs was a *Tethys*, showing that he was aware of the analogy of the Bivalves with the Tunicates. In other respects, however, he added to the confusion. After that Bohatsch § and Plancus ‖ figured and described some species. Baster ¶ describes a species, and gives it the name of *Ascidium* (from ασκος, a skin-bottle), at the same time adding a very just remark on the analogy of its internal structure with that of the oyster. This analogy was noticed also by Pallas, who proposed the union of the *Tethyum* and *Ascidium* **, which Linnæus carried out in the 12th edit. of his Systema Naturæ, uniting the species, noticed by Bohatsch and Kœnig, under the name of *Ascidia*, and confining the name *Tethys* to the inhabitants of the Bivalves.

* Hist. Anim. lib. iv. c. vi., and De Part. Anim. lib. vi. c. v.
† De Piscibus, 1554. ‡ De Aquat. 1553.
§ De quibusd. Anim. Marin. 1761.
‖ Conchis minus notis, pl. v. & vii. 1739.
¶ Opusc. subseciv. ii. x. 5. 1764.
** Miscell. Zoolog. 74. 1767.

Subsequently, O. F. Müller *, O. Fabricius †, Dicquemare ‡, Pallas §, and others, described and figured several *Ascidiæ*, which Brugière ‖ and Gmelin ¶ collected together in their respective works, without adding much to the knowledge of the group. Cuvier's first observations on the simple Ascidians were begun in 1797, and his memoir on their anatomy was published in 1815.** About the same time were published the researches of Schalk †† on the anatomy, and of Carus ‡‡ on the anatomy and development of the Ascidians. The memoirs of Péron and Lesueur §§ on the *Pyrosoma*, Desmarest and Lesueur ‖‖ on the *Botryllus*, and particularly the elaborate work of Savigny ¶¶ on the simple and compound Ascidians, enabled naturalists to make rapid advances in the knowledge of this family. With respect to the Salpians, Brown ***, Forskahl †††, and Tilesius ‡‡‡ were the first to figure and describe any forms of this group. Considerable confusion with regard to these forms existed in the classifications of Linnæus, Pallas, Brugière, and Bosc, and indeed in the earlier writings of Lamarck and Cuvier, until the latter had an opportunity of working out the anatomical characters of these animals.

The earlier works on the various branches of this subject have been succeeded by the publication of the researches of many distinguished naturalists. We are chiefly indebted to the labours of Cuvier, Savigny, Carus, MacLeay, and Van Beneden, for information on the structure and development of the simple Ascidians; to the researches of Cuvier, Kuhl and Van Hasselt, Chamisso, Eschricht, and Krohn, for the history of the Salpians; and to Lesueur, Desmarest, Savigny, Lister, Sars, Milne-Edwards, Audouin, and Forbes, for our knowledge of the compound ascidian forms.

And, indeed, since the commencement of the present century, the organisation of this group has been studied with great care, rewarding the labours of naturalists with discoveries of the highest interest. "It was in the animal of the *Salpa*," says Van Beneden, "that Van Hasselt discovered a heart of such extraordinary character, changing incessantly its auricle to ventricle and its ventricle to auricle, its ar-

* Zool. Dan. Prodromus, 1766.
† Fauna Groenland, 1780.
‡ Journal de Physique, 1777.
§ Spicilegia Zoologica, 1774, and Mém. de Pétersbourg.
‖ Encyclopédie Méthodique; Vers Mollusques.
¶ Systema Naturæ, edit. 13.
** Mémoires du Muséum, tom. ii.
†† De Ascidiarum Structurâ, Halle, 1814.
‡‡ Meckel's Archiv, tom. ii. and Acta Cur. Nat. Bonn, vol. x.
§§ Annales du Muséum, tom. iv.
‖‖ Bull. Nouv. Soc. Philom. 1815, and Journal de Physique, tom. lxxx.
¶¶ Mém. Anim. sans Vertèbres, 2e part.
*** Natural History of Jamaica.
††† Descript. Animalium, &c. 1776.
‡‡‡ Ann. Hist. Nat. Leipzig, 1802.

teries to veins and its veins to arteries. The Ascidians, too, furnish the first examples of complete metamorphosis in the lower ranks of the animal kingdom. The honour of this discovery is due to MM. Audouin and Milne-Edwards. From the late discoveries of M. Sars, these metamorphoses increase in interest, and appear tobe still more remarkable. And, lastly, the Ascidians have contributed very considerably to our knowledge of the circulatory apparatus of the Mollusca generally."

The term *Tunicata* was first used by Lamarck; its synonyms are *Tethya*, Auct.; *Soft-shelled Molluscs*, Hunter; *les Acephales sans coquilles*, Cuvier; *Acephalophora heterobranchiata*, Blainville; *Tunicaries*, Kirby; *Gymnacephala*, Bronn. The CLASS of animals to which it is applied may be zoologically defined as consisting of acephalous Molluscs; with a soft shell or test, organised, coriaceous or gelatinous, frequently destitute of mineral constituents, having a large proportion of cellulose in its composition: animals single or aggregate; the test of each animal provided with two apertures, one branchial, the other anal; the mantle forming an interior coat; the branchiæ attached wholly or in part to the internal surface of the mantle; the mouth, without labial tentacles, placed below the branchial apparatus; animals hermaphrodite, undergoing metamorphosis in their young state.

The cavity, whether of single or compound Tunicates, is occupied by a more or less muscular sac, provided, like the external tunic, with two orifices. This sac, identical with the "mantle" of the Acephalans, is attached to the inner surface of the test, generally only at the orifices, and contains the viscera. The digestive, reproductive, and circulatory organs are disposed at the base of the sac, and its upper and larger portion, lined with, or traversed by, the branchiæ, forms the branchial cavity. This is placed at the commencement of the alimentary canal, of which it forms as it were the antechamber. The branchiæ have generally the form of ridges, more or less complicated, and seldom symmetrical. The alimentary canal is simple, and barely distinguishable into gullet, stomach, and intestine. It is always convoluted or folded once on itself. The liver adheres to the stomach, and in many species is divided into distinct lobes. The heart consists of a slightly bent, contractile tube, and is situated near to or within the intestinal loop. The reproductive organs, consisting of ovary and testicle, are often lodged in the fold of the intestine.

The animal of these "soft-shelled" Molluscs has very close affinities with that of the other Acephalans, especially the lamellibranchiates. And "were the test of an Ascidian converted into a hard shell, symmetrically divided into two plates, connected together dorsally by cartilage, and capable of separation so as to expose the mantle along a ventral mesial line, whilst the orifices protruded at one extremity, it would present the closest similarity with many bivalve Molluscs."* (Forbes.)

All the *Tunicata* are free during the earlier periods of their existence; some remain permanently free, floating in the water (*Salpæ*, &c.), but the generality (*Botrylli, Ascidiæ*, &c.) become fixed to shells, seaweeds, and other marine bodies. Some exist as distinct individuals (*Ascidia*, *Cynthia*, &c.), whilst various degrees of combination are affected by others (*Botryllus*, *Clavellina*, *Pyrosoma*, &c.); and some are simple in one generation and combined in the next (*Salpa*).

From the above-mentioned various conditions of individualism or aggregation under which these animals exist, the family is divisible into two groups — the *simple* and the *aggregate*. Such forms of the latter group as were known to the earlier naturalists were, from a general similarity of appearance, classed by them with *Alcyonia*. In the former group have been placed, until a late date, the numerous species of the *Salpidæ*, which now however, like the above-mentioned groups, have been separately treated of and illustrated in memoirs and monographs devoted to them. Indeed, although the expressions, simple and aggregate, as will be seen hereafter, are very convenient in describing the physiology of the *Tunicata*, yet late researches have shown that the conditions to which they refer have but a subordinate value in reference to the natural grouping of the class.

As may naturally be inferred from what is stated above, the *Tunicata* have been subdivided in various manners. The arrangement we are inclined to adopt is as follows: —

TUNICATA	Dichitonida, *Fleming*. Inner sac more or less detached from the external tunic; united to it at the two orifices. Branchiæ, large, equal, spread on the inner surface of this sac. Branchial orifice with an inner membranaceous ring and circle of tentacles.	Fixed. Branchial and anal orifices not opposite to each other. Branchiæ conjoined.	Ascidiadæ. Clavellinidæ. Botryllidæ.
		Floating. Branchial and anal orifices opposite to each other. Branchiæ disjoined.	Pyrosomidæ.
	Monochitonida, *Fleming*. Inner sac adhering throughout to the external tunic. Orifices without tentacular fringes.	Branchial and anal orifices opposite to each other.	Salpidæ.
		Branchial and anal orifices not opposite to each other.	Pelonaiadæ.

* We may particularly mention the *Myæ*, *Pholades*, &c.

Dichitonida. — Family Ascidiadæ, E. Forbes. Synonyms: *Tethyes simples*, Savigny; *Ascididæ*, MacLeay; *Tuniciers libres ou Ascidiens*, Lamarck; *Ascidiaria*, Stark; "*les Isolées*," Cuvier; *Ascidiacea*, pars, Blainville; *Ascidiens simples*, Milne-Edwards; *Ascidiens*, Van Beneden.

Body simple, fixed; animals isolated or gregarious; not united into groups by a common integument; oviparous, not gemmiparous. The following genera are members of this family: —

Ascidiadæ, vel Ascidiæ simplices	Branchiæ not plicated		Ascidia.* Molgula.
	Branchiæ plicated	Sessile	Cynthia. Dendrodoa. Chelyosoma.
		Pedunculated	Boltenia. Cystingia. Bipapillaria.

Genus *Ascidia*, Baster and Linnæus. — "Rarely," says Professor E. Forbes, "is the dredge drawn up from any sea bed at all prolific in submarine creatures, without containing few or many irregularly shaped leathery bodies, fixed to sea-weed, rock, or shell, by one extremity or by one side, free at the other, and presenting two more or less prominent orifices, from which, on the slightest pressure, the sea-water is ejected with great force. On the sea shore, when the tide is out, we find similar bodies attached to the under surface of rough stones. They are variously, often splendidly, coloured; but otherwise are unattractive, or even repulsive,

Fig. 766.

Ascidia mammillata. (*Original.*)

a, branchial orifice, open; *b*, anal orifice, closed.

in aspect. These creatures are *Ascidiæ*, properly so called. Numbers of them are often found clustering among tangles, like bunches of some strange semitransparent fruit." Some species (in France, *vulgò* "le vichet") on the coasts of the Channel † and the Mediterranean, and in the Chinese Seas, are valued as articles of food In this genus (*fig.* 766.) the body is sessile; test, coriaceous or gelatinous; branchial orifice eight and six-lobed; branchial sac not plicated, surmounted by a circle of simple tentacular filaments.

Genus *Molgula*, E. Forbes; synonym, *Ascidia*, Auct. — Body more or less globular, attached or free ‡; test membranous, usually invested with extraneous matter; orifices on very contractile and naked tubes, the branchial six-lobed, the anal four-lobed.

Genus *Cynthia*, Savigny; synonym, *Ascidia*, Auct.—Body sessile, fixed or unattached; test coriaceous; branchial and anal orifices opening in four rays or lobes; branchial sac longitudinally plicated, surmounted by a circle of tentacular filaments.

Genus *Dendrodoa*, MacLeay. — Body subcylindrical, fixed, sessile; test coriaceous, smooth; orifices terminal, minute, indistinctly quadrifid; branchial sac plicated; tentacula

* Some very good observations on the subdivisions of the *Ascidiæ* have been made by M. Savigny, Dr. Fleming, and Mr. MacLeay. But we must not here enter further into details. The following classification is that adopted wholly or in part by the above authors respectively: —

Ascidiæ	Phallusiæ	Pyrena. Phallusia. Ciona.
	Cynthiæ	Cynthia. Cæsira. Styela. Pandocia. Dendrodoa.

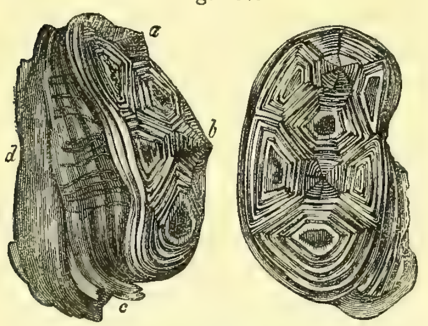
† "At Cette," says Van Beneden, "*Ascidiæ* are taken regularly to market; and *Cynthia microscomus*, although so repulsive externally, furnishes a very delicate morsel, much sought after by some."

‡ Individuals of several species of Ascidians, viz. of the following genera, *Molgula*, *Cynthia*, *Cystingia*, *Bipapillaria*, and *Pelonaia*, are found unattached. These animals, however, cannot be said to have an entirely free existence, their tests, whether peduncled or otherwise, being usually more or less imbedded in sand or mud, and frequently held to their anchorage by the agglutination of the surrounding sand-grains to their outer surface. But from such a position they are easily disturbed, unless when they are lodged within the mud-filled cavities of old shells and of water-worn stones, as is the case with the *Pelonaia*.

simple (*fig.* 778). *Dendrodoa* closely agrees with *Cynthia* in its branchial reticulations and its digestive apparatus; but, as Mr. Mac Leay has observed, of the two ovaries possessed by *Cynthia*, only one, and that the left, is found in *Dendrodoa*, whilst the right ovary alone is present in *Pandocia*.

Genus *Chelyosoma*, Broderip and Sowerby. — Body depressed, oblong, fixed, sessile; test coriaceous, its upper surface consisting of eight somewhat horny, angular plates; orifices small, prominent, perforating the plated surface, each surrounded by six triangular valvules (*fig.* 767.); branchiæ plicated; tentacles simple.

Fig. 767.



Chelyosoma Macleayanum. (*After Broderip and Sowerby.*)

a, branchial orifice; *b*, anal orifice; *c*, coriaceous envelope of the sides; *d*, stone to which the animal is fixed.

To the *Ascidiadæ* we may provisionally join the following obscure form, occurring on the coasts of South America:

Genus *Fodia*, Bosc. — Body oval, mammillated, divided throughout its length by a vertical partition, which contains the stomach, into two unequal tubes open at each end by an orifice, the superior aperture rather depressed and irregularly toothed, the inferior bordered by a circular collar forming a sucker, and serving to attach the animal to extraneous objects.

Genus *Boltenia*, Savigny; synonym, *Ascidia*, Auct. — Body more or less globular, fixed, pedunculated, attached sometimes to the stem of another individual; test coriaceous; orifices lateral, and each cleft into four rays; branchial sac longitudinally plicated; surmounted by a circle of compound tentacula.

Genus *Cystingia*, MacLeay. — Body globular, fixed, pedunculated; test subcoriaceous; branchial orifice quadrifid, lateral; anal irregular, terminal; branchial sac plicated; tentacula compound.

Genus *Bipapillaria*, Lamarck. — Body more or less globular, free, pedunculated; test membranous; the extremity of the body opposite to the attachment of the peduncle bearing two equal, conical papillæ, having their apices perforate; each orifice furnished with three very short, stiff, setaceous, retractile tentacles.*

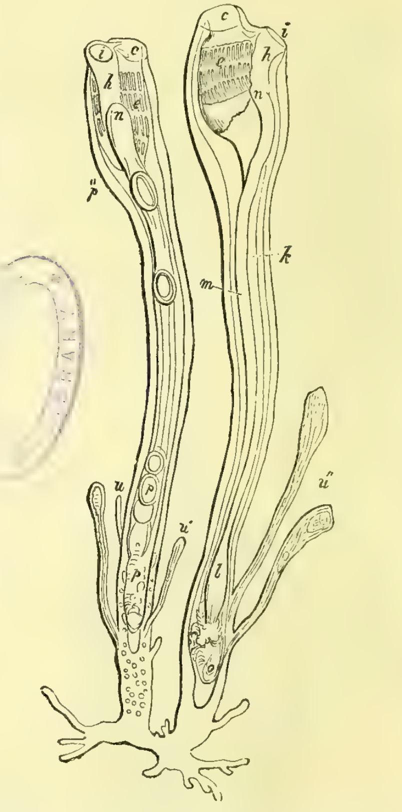
* This obscure genus was established by Lamarck from a description and figure in Péron's MSS.

Family Clavellinidæ, E. Forbes. Synonyms: *Ascidiæ*, Auct.; *Tethyes simples*, pars, Savigny; *Ascidiens sociales*, Milne-Edwards; *Pérophoriens*, Van Beneden.

Body compound, fixed; animals connected by creeping, tubular prolongations of the common tunic, through which the blood circulates. This family comprises two genera: —

Genus *Clavellina*, Savigny; synonym, *Ascidia*, Auct. — Body elongated, erect, more or less pedunculated; test smooth and transparent; branchial and anal orifices without rays; thorax usually marked with coloured lines (*fig.* 768.).

Fig. 768.



Clavellina producta. Group of two adult and several young individuals, magnified about five times. (*After Milne-Edwards.*)

c, branchial orifice; *e*, branchiæ; *h*, cloaca; *i*, anal orifice; *k*, inner tunic or mantle; *l*, stomach; *m*, intestine; *n*, termination of the anus and oviduct in the cloaca; *o*, the heart; *p*, ovary; *p''*, ova ready to pass into the cloaca; *u*, *u'*, *u''*, reproductive buds, in different degrees of development, springing from the abdomen of the adults.

Genus *Perophora*, Wiegmann.*—Individuals pedunculated, suborbicular, compressed; thorax not lineated by granular bands.

* This curious little social Ascidian was first described and illustrated by Mr. J. Lister, in a paper "On the Structure and Functions of tubular and cellular Polypi and of the Ascidiæ," Philos. Trans. 1834. Lister gave no name to the animal,

Family Botryllidæ, MacLeay. Synonyms: *Alcyonia*, Auct. prior.; *Téthyes composées*, Savigny; *les Réunis* ou *Botryllaires*, Lamarck; *les Agrégés*, Cuvier; *Ascidiacea*, pars, Blainville; *Ascidies composées*, Milne-Edwards; *Polyascidiens*, Van Beneden.

Body compound, fixed; animals associated; the tests fused together, forming a common mass in which the animals are imbedded in one or more groups or "systems;" the individuals not connected by any internal union; oviparous and gemmiparous.

"If, when walking on the sea-shore, about low-water mark," says the distinguished naturalist previously quoted, "we turn over large stones, or look under projecting eaves of rock, we are almost sure to see translucent jelly-like masses of various hues of orange, purple, yellow, blue, grey, and green, sometimes nearly uniform in tint, sometimes beautifully variegated, and very frequently pencilled as if with stars of gorgeous device; now encrusting the surface of the rock, now descending from it in icicle-like projections. These are compound Ascidians. A tangle or broad-leaved fucus, torn from its rocky bed, or gathered on the sand, where the waves have cast it after storms, will show us similar bodies, mostly those star-figured, investing its stalks, winding among the intricacies of its roots, or clothing with a glairy coat the expanse of its foliated extremities. . . . In examining these bodies, we find that it is not a single animal which lies before us, but a commonwealth of beings, bound together by common and vital ties. Each star is a family, each group of stars a community. Individuals are linked together in systems, systems combined into masses. . . . Indeed, few bodies among the forms of animal life exhibit such exquisite and kaleidoscopic figures as those which we see displayed in the combinations of the compound Ascidians."

Previous to the researches of Savigny, the *Botryllidæ* were regarded as *Alcyonia;* Gaertner (1774) and Renieri (1793) being the only naturalists who had suspected their compound nature and true affinities.* "The Memoir of Savigny, published in 1816, however, threw entirely new and unanticipated light on their nature. He showed that they were essentially Ascidians, differing from the simple forms only in being united into more or less complicated systems."†

In the arrangement of Professor Milne-Edwards the family is subdivided as follows:

Botryllidæ, vel Ascidiæ compositæ	Polyclinina	Bistellata	Sigillina.
		Unistellata	Polyclinum. Aplidium. Sidnyum. Synoicum. Amaroucium.†
	Didemnina	Bistellata	Distomus Diazona.
		Unistellata	Didemnum. Eucælium. Leptoclinum.
	Botryllina		Botryllus. Botrylloides.

The tribe *Polyclinina* (*les Polycliniens*, Milne-Edwards) is characterised principally by the division of the body into three distinct portions, viz. a thorax, a superior abdomen, and a post-abdomen. It has, however, other anatomical peculiarities, such as the great development of the organs of generation, and the position of the heart at the inferior extremity of the body. This group comprehends numerous species, and is divisible into two natural sections, recognised by the external conformation of the anal orifice. In one division (*P. bistellata*) this orifice is surrounded with a regular circlet of rays or marginal lobules, and is exactly similar to the branchial orifice. In the other division (*P. unistellata*) the anal differs from the branchial orifice in not being rayed, or at least in having merely irregular marginal lobules.

Genus *Sigillina*, Savigny. — Common body a solid, elongated, erect cone; gelatinous, pedunculated, isolated or attached to similar cones, consisting of a single system of many individuals disposed one above another in irregular circles; branchial and anal orifices each with six rays; abdomen larger than thorax; post-abdomen long and slender (*fig.* 769.).

Genus *Polyclinum*, Savigny.—Common body gelatinous or cartilaginous, polymorphous, sessile or slightly pedunculate; systems numerous, convex, somewhat stellate, with central cloacal cavities; individuals (10 to 150) placed at very unequal distances from their common centre; the cavity in the common tegument occupied by each animal is divided into three chambers one above another by contractions of its calibre; abdomen much smaller than the thorax; post-abdomen pedunculate.

Genus *Aplidium*, Savigny; synonym, *Alcyonium*, Auct. — Common body gelatinous or cartilaginous, sessile; systems very nume-

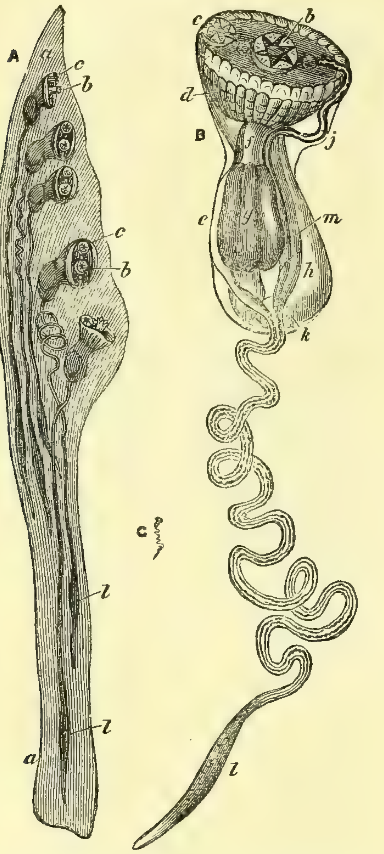
but Professor Wiegmann subsequently (Jahresbericht in Archiv. 1835) gave it the appellation of *Perophora Listeri.*

* For the early history of this genus, consult the Memoir on *Botryllus stellatus* by MM. Desmarest and Lesueur, Journal de Physique, tom. lxxx. 1815.

† In the latest ("commemorative") edition of Cuvier's Règne Animal, M. Milne-Edwards has established a new subgenus, *Parascidia*, which has eight marginal teeth on the buccal orifice.

rous, slightly prominent, annular or subelliptical, without central cavities; the animals (3 to 25) are placed in a single row, at

Fig. 769.



Sigillina australis. (*After Savigny.*)

A. *Vertical section of a cone, or "system," showing the distribution of the animals, magnified.*
B. *Isolated individual, magnified.*
C. *Natural size of isolated individual.*
a, test, or external envelope; *b*, branchial orifice; *c*, anal orifice; *d*, thorax; *e*, abdomen; *f*, œsophagus; *g*, stomach; *h*, intestine; *j*, thoracic sinus; *k*, intestinal loop; *l*, ovary; *m*, oviduct.

equal distances from their common centre; branchial orifice six-rayed; division of the thorax and abdomen not always distinctly marked.

Genus *Sidnyum*, Savigny. — Common body gelatinous, presenting a series of closely grouped cones, truncated and starred at the summit, rising from a common incrusting base; each cone composed of a fascicle of individuals, varying in number from five or six to ten or twelve, and forming a margin around a depressed centre. The animals partake of the characters of those of *Synoicum* and *Aplidium*, resembling the former in the structure of their stomach, and the latter in their branchial sac. Each has an eight-toothed branchial orifice and a simple tubular vent folded against the thorax. The ovary is peduncled, and very conspicuous at the extremity of the animal. (Forbes.)

Genus *Synoicum*, Phipps.*—Common body semicartilaginous, cylindrical, peduncled, isolated or attached to similar cylindrical bodies; system single, circular, comprising six to nine animals, terminal; branchial orifice six-rayed; anal orifice having six very unequal rays, the three largest forming the exterior margin of the central star; post-abdomen sessile.

Genus *Amaroucium*, Milne-Edwards.—Common body fleshy or coriaceous, polymorphous, subpedunculate or sessile, and incrusting; systems numerous; individuals arranged irregularly around common cloacal apertures; divisions of the thorax and abdomina faintly marked. This genus resembles *Aplidium* and *Synoicum* in the general form of the animal, and *Polyclinum* in the presence of a central common cavity to each system (*fig.* 782).

The tribe *Didemnina* (*les Didemniens*, Milne-Edwards) is formed of all the compound Ascidians whose body is distinctly divided into two parts, thorax and abdomen. These closely approach the *Clavellinæ*, and are distinguished from the *Polyclinina* by the absence of the post-abdomen and by the position of the organs of generation and the heart, which are raised up by the side of the intestine. This tribe, like the *Polyclinina*, is divided into two groups, according to the presence or absence of marginal rays around the anal orifice. M. Milne-Edwards observes that the bistellate group (*Distomus* and *Diazona*) forms a connecting link between the *Clavellinæ* and the *Botryllidæ*.

Genus *Distomus*, Gaertner†; synonyms, *Alcyonium*, Auct., *Polyzona*, Fleming. — Common body semi-cartilaginous, polymorphous, sessile; systems numerous, usually circular; individuals placed in one or two ranks at unequal distances from their common centre. Both orifices six-rayed.

Genus *Diazona*, Savigny. — Common body gelatinous, orbicular, sessile or subpedunculate; system single, expanded into a disc, comparable to that of a flower or of an Actinia; animals very prominent, arranged in concentric circles (*fig.* 770.); branchial and anal orifices six-rayed; abdomen peduncled; ovary enclosed in the intestinal loop.

Genus *Didemnum*, Savigny.—Common body coriaceous, polymorphous, sessile and incrusting; systems numerous, compressed, without central cavities or distinct circumscription; animals without any appreciable order of arrangement; abdomen peduncled; ovary placed by the side of the intestinal loop, increasing in length when the eggs are fully developed.

Genus *Eucœlium*, Savigny. Common body gelatinous, sessile and incrusting; systems numerous, without central cavities or distinct

* Voyage towards the North Pole, 1773, p. 199, pl. 13.

† Gaertner, apud Pallas, Spicilegia Zoologica, 1774.

Fig. 770.

Diazona violacea, magnified. (*After Savigny.*)

circumscription; animals sometimes scattered, sometimes arranged in a quincunx; branchial orifice circular, without distinct rays; anal orifice very minute and indistinct; abdominal viscera pushed up by the side of the thorax.

Genus *Leptoclinum*, Milne-Edwards.—Common body sometimes coriaceous, sometimes gelatinous, thin, sessile and incrusting; systems few; individuals arranged irregularly around common cloacal cavities; abdomen peduncled, short, smaller than the thorax.

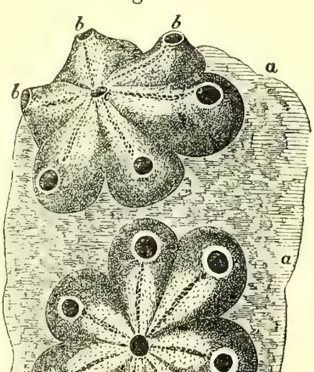
The tribe *Botryllina* (*les Botrylliens*, Milne-Edwards) comprises those compound Ascidians that are united in systems around common excretory cavities or *cloacæ*, and whose bodies are not divided into a distinct thorax and abdomen, the viscera being pushed forward on the side of the branchial cavity, and forming with the thorax an ovoid mass.

Genus *Botryllus*, Gaertner; synonyms, *Alcyonium*, Auct., *Polycyclus*, Lamarck.—Common body gelatinous or cartilaginous, sessile and incrusting; systems numerous, prominent, round or star-shaped, with central cavities; individuals, six to twenty in each system, lying horizontally with the vent far from the branchial orifice; branchial orifice simple (*fig*. 771.).

Genus *Botrylloides*, Milne-Edwards.—This genus resembles the foregoing in most respects, except that the stars formed by the systems of animals are irregular and ramifying; the cloacæ being prolonged into the common mass as irregular internal channels, on each side of which the individuals are placed in linear series, instead of having a simple star-like arrangement around the cloacæ, as in *Botryllus*. The animals of *Botrylloides*, moreover, have a nearly vertical position, and their orifices are closely approximate (*fig*. 783.).

We should perhaps also refer to the group of the *Botryllidæ*, an obscure form, first noticed by Molina*, and subsequently named *Pyura* by Blainville, and considered by the latter to form a link between the simple and compound Ascidians. M. Blainville gives the following characteristics.

Fig. 771.



Botryllus violaceus. Two of the star-like systems, magnified. (*After Milne-Edwards.*)

a, *a*, common test; *b*, *b*, *b*, some of the branchial orifices; *c*, the common anal orifice of one of the systems.

Genus *Pyura*, Blainville.—A pyriform body, with two small short tubes, occupying a cell in the external envelope, and forming, by its union with 10 to 12 individuals, a kind of polymorphous mass somewhat resembling honeycomb, apparently without any external orifice.

* Saggio sulla Historia naturale del Chili. Bologna, 1782, 4to.

Family PYROSOMIDÆ. Synonyms: *Lucies composées*, Savigny; *Tuniciers réunis*, pars, Lamarck; "*les agrégés*," pars, Cuvier; *Salpiens agrégés*, Blainville; *Lucidæ*, MacLeay; *Pyrosomiens*, Milne-Edwards and Van Beneden. The Pyrosomians are represented by three or four species of the single genus *Pyrosoma*.

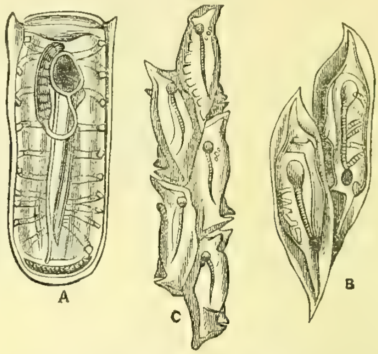
They inhabit the Mediterranean and the warmer parts of the ocean; in the former at times their abundance is a source of dread to the fishermen, sometimes even completely clogging their nets; and in certain oceanic regions they are met with in almost incredible profusion. Their delicate and transparent forms, their elegant tints, and their unrivalled phosphorescence render them the most beautiful of Molluscs, and objects of admiration to the naturalist and the voyager. Mr. Bennett relates that, during a voyage to India, the ship, proceeding at a rapid rate, continued during an entire night to pass through distinct but extensive fields of these Molluscs, floating, and glowing as they floated, on all sides of her course. Enveloped in a flame of bright phosphorescent light, and gleaming with a greenish lustre, the Pyrosomes, seen at night, in vast shoals upwards of a mile in breadth, and stretching out till lost in the distance, present a spectacle the glory of which may be easily imagined. The vessel, as it cleaves the gleaming mass, throws up strong flashes of light, as if ploughing through liquid fire, which illuminates the hull, the sails, and the ropes with a strange unearthly radiance.

Genus *Pyrosoma*, Péron. — Common body semi-cartilaginous, floating, cylindrical, 2 to 14 inches long, ½ to 3 inches in circumference; bearing externally numerous pointed processes, hollow and mammillated within, and open at one of its extremities only. Animals associated in a verticillate arrangement, having two orifices, one at each extremity; elongated, fusiform, tapering at the outer, and obtuse at the inner extremity; united at the circumference of the middle portion, by the fusion of the tests to one another into rings, more or less regular, and varying in number according to species, so that the whole forms the long cylinder above described.

MONOCHITONIDA. — Family SALPIDÆ, Forbes. Synonyms: *Salpæ*, Auct.; *Thalides*, pars, and *Lucies simples*, Savigny; *Biphores*, Brugière; *Biphoridæ*, MacLeay; *Tuniciers libres*, pars, Lamarck; "*les isolées*," pars, Cuvier; *Salpacea*, pars, and *Salpiens simples*, Blainville; *Salpiens*, Van Beneden. The Salpians are free, swimming in the ocean; plentiful in the Mediterranean and the warm parts of the ocean; occurring also occasionally in the Norwegian and North British seas. In shape they resemble a short and wide tube, sometimes oval or cylindrical, sometimes more or less square in its transverse section, and varying considerably in size according to species, from half an inch to 8 or 10 inches in length.

The test is thin and transparent, open at the ends and often supplied with terminal and lateral processes. The mantle lines the test, and is more or less adherent throughout; its interior constitutes the branchial cavity; it is provided at one of the terminal openings with a more or less perfect valvular apparatus; and contains a branchial fold traversing it obliquely. Near one extremity the chief viscera are grouped together into a conspicuous mass (the "visceral nucleus" of authors), to which the brilliant tints of the liver usually impart an orange, brown, or reddish hue (*fig.* 772.).

Fig. 772.



Salpæ, isolated and associated.

A. *S. runcinata*, solitary; B. *S. runcinata*, associated; C. *S. zonaria*, aggregated.

This family is of considerable interest on account of their singular mode of reproduction, discovered by Chamisso, and on account of the philosophical generalisations partly founded thereon by Steenstrup. These animals occur under two distinct conditions, being at one time solitary, and at another associated into circular or lengthened groups — termed garlands, cordons, ribands, and chains (*fig.* 772. B and C). The Salpa-chains, varying in length from a few inches to many feet, swim through the tranquil water with a regular serpentine movement, and are often regarded by sailors as sea-serpents; but when taken from the water the individuals of the group are easily detached. Thus, in consequence of accidents, separate members of these chains are often met with in seas abounding with these Molluscs; but other, separate, *Salpæ* are also met with that have never been united to others, and differ considerably in form from the associated ones (*fig.* 772. A).

Chamisso, however, discovered that such *permanently* solitary *Salpæ* do not belong to species distinct from those united in chains, however dissimilar (and they are usually so dissimilar as to appear even generically distinct), but are either the parents or the progeny, as the case may be, of the aggregate forms; and that chained *Salpæ* do not produce chained *Salpæ*, but solitary *Salpæ*, which in their turn do not produce solitary, but chained *Salpæ*. Consequently, as Chamisso graphically observed, "a *Salpa*-mother is not like its daughter or its own mother, but resembles its sister, its grand-daughter, and its grand-mother."*

This family is mainly represented by the

* Forbes, British Molluscs, p. 48.

genus *Salpa*, Forskahl; synonyms *Thalia*, Brown; *Holothuria*, Linné and Pallas; *Dagysa*, Banks and Solander; *Biphora*, Brugière; *Tethis*, Tilesius; *Pegea* and *Iasis*, Savigny. The characteristic features of this genus are detailed above.

Quoy and Gaimard * established for some animals nearly allied to the Salpes and inhabiting the coasts of Amboina, the genus *Doliolium*, the characters of which are, its having the form of a little cask open at the ends; from two to ten lines in length; the anterior extremity a little prominent; marked with circles in relief on the external surface; and having internal branchia, divided into two branches; and a heart and a dorsal vessel, situated near the union of these branches. This name had also been previously given by Otto † to a genus established by him on a Mediterranean *Salpa*, mutilated by a crustacean of the genus *Phronyme*, that had made it its habitation. This form, like *Salpa triangularis* and *S. polymorpha* (by Quoy and Gaimard, and Bory de Vincent), has been erroneously regarded as belonging to the family of *Diphydes*. MM. Löwig and Kölliker, however, who found the tissue of *Doliolium* to be identical with the peculiar substance of the test of other *Tunicata*, have pointed out its true affinities, and placed it with the *Salpidæ*.

Family Pelonaiadæ, Forbes. — This family is represented by two rare animals, both inhabitants of the Scottish seas, constituting two species of a single genus, *Pelonaia*, established by Professor E. Forbes and Professor Goodsir.‡ We have derived our description of the general and anatomical characters of these interesting Molluscs from the detailed account given of them by the original discoverers.

Genus *Pelonaia*, Forbes and Goodsir. — Animal simple, unattached. Test more or less cartilaginous, smooth or wrinkled, elongated, and cylindrical; anterior extremity bearing two orifices, four-cleft, without tentacles, and placed on the same plane, on two equal, approximate, papillose eminences; posterior extremity ending in a blunt point; mantle adherent to the test. The *Pelonaiæ* live buried in mud, quite unattached to any other body, and are extremely apathetic animals, presenting scarcely any appearance of motion.

Anatomy and Physiology of the Tunicata.

It will be most convenient to describe the *test* generally for the whole tunicate class, and the rest of their anatomy under the heading of each of the families.

Test or Shell. — The test or external envelope of the *Ascidiadæ* is subject to considerable variation of shape; from the bottle-like form of the *Ascidia* (*fig.* 766.), to the flat, patella-like form of *Chelyosoma* (*fig.* 767.); it is elastic, varying very much in its thickness and consistence in different species. In colour it varies considerably, being occasionally nearly black, sometimes red, orange, yellow, or milky white. Its surface is sometimes smooth, often tuberculated, covered with hairs or spines, or otherwise roughened. Sometimes minute patches of horny tissue or hardened epidermis rise up irregularly on the surface of the test; in other cases these are placed in a tessellated arrangement. In the peculiar and unique form, *Chelyosoma*, first noticed by Messrs. Broderip and Sowerby, and since more fully described by Professor Eschricht, the upper surface of the test is occupied by eight large, horny, polygonal plates arranged somewhat like the shell-plates of a tortoise, and by several smaller triangular plates, which form two circles, one around the branchial, and the other round the anal aperture of the animal (*fig.* 767.). The large plates are so disposed that the branchial orifice is surrounded by three plates, and the anal by four, besides that which is intermediate and abuts upon both: this latter plate is hexagonal, the sides in contact with the orificial valvules are lunated. The three plates near the branchial orifice are much larger than the four which are near to the anal orifice. Each of the plates is marked with three or four elevated striæ, which are near to the edges of the plate, and parallel with them, leaving an area in the centre, and giving rise to a general resemblance to the external plates of the shell of a land tortoise. The orifices are very small, and are surrounded by six triangular valvules, each transversely striated, and, when shut, rising from the surrounding surface in the form of a cone. The lower or adherent part of the test of *Chelyosoma* is coriaceous, with occasional slight traces of separation into plates.

The test of *Ascidiæ* is frequently covered with innumerable smaller animals and their spawn. Modiolæ and Annelids burrow in it; Cirrhipeds, naked Molluscs, and Actiniæ lodge upon it; and Corallines cover it sometimes with a little forest; a condition fully justifying the denomination of "microcosmus," bestowed by Redi * on a Mediterranean species. Occasionally, as in *Ascidia conchilega* and *Molgula oculata*, the animal works up extraneous matter, as gravel, fragmentary shells, &c., with the external surface of the test. It is by this shell or test that the animal fixes itself. In the sessile species, the tissue of the base or the side of the test interlaces with the stems of sea weeds and corallines, or closely adheres to the surface of another ascidian sac, or of a stone, a shell, a crab, or other object. In the peduncled forms this tunic is at one point prolonged into a tubular process or stem, the distal extremity of which is attached to marine bodies in the same manner as the base of the sessile tests. In *Cystingia* and *Bipapillaria*, however, this process or stalk appears to be less perfectly developed, and not to be al-

* Voyage de l'Astrolabe, Zoologie, tom. iii.
† Nova Acta Academ. Nat. Curios. t. xi.
‡ Jameson's Edinb. New Philosoph. Journal, vol. xxxi. 1841.

* Opuscula varia Physiologica, 3 vols. 12mo. Lugd. Batav. 1725.

together adapted to maintain a permanent attachment to a fixed body.

The external envelope of the *Ascidiadæ* is always perforated by the two apertures characteristic of the *Tunicata*, and analogous to the prolonged respiratory orifices of the *Cardiaceæ* and other *Acephala*. One of these apertures *, nearly always placed at the summit of the test, receives the sea-water, and admits it into the branchial cavity. The second aperture † is placed a little lower than the first, and is in communication with the rectum and oviduct. In *Boltenia* the orifices are lateral; in *Cystingia* the branchial orifice is lateral, and the anal terminal; the oral orifice being always the highest in relative position, and nearest to the insertion of the pedicle by which the animal is suspended. In *Chelyosoma* and *Dendrodoa* the orifices are placed on the same plane; in the former, on the nearly flat superior surface of the animal, and in the latter they are terminal.

The edges of the orifices are more or less crenulate or divided. The branchial orifice is 8–9 rayed, and the anal 6 rayed, in *Phallusia;* both orifices are 4-fid in *Cynthia*, *Boltenia*, and *Dendrodoa*. When contracted, they are thrown into longitudinal folds; this is the more observable when the orifices are somewhat prolonged into tubes.

The test receives from the body bloodvessels, which its semitransparency in some species allows the eye to follow to the extreme ramifications. In the thinner tests the vessels are but few, and sometimes altogether escape observation; but in the thick pellucid test of *Ascidia mammillata* the eye can discern an extensive network of vascular ramifications. The bloodvessels enter the test near the base. The internal surface of the test has often a glistening and pearly appearance, and is always lined with an epithelium. In *Boltenia reniformis* this is a loose tissue, and forms a slight attachment to the external surface of the muscular sac or mantle of the body.

In *A. mammillata* a thin vertical septum traverses a part of the cavity of the test.

The test of the *Clavellinidæ* is very similar in consistence and general appearance to that of some of the more delicate species of the *Ascidiadæ*, but differs materially in having tubular prolongations running from its base, which are traversed by vessels continuous from one individual to another, and from which root-like processes young individuals are continually being produced by the process of gemmiparous reproduction (*fig.* 768.).

The tube-like test of the *Salpidæ* is "semicartilaginous, or gelatinous, seeming as if carved in crystal," its transparency rendering conspicuous the brilliant hues of the liver of the contained animal. It is usually more or less angular, bearing elongated crests, denticles, and other processes, by means of which the cohesion of the aggregated individuals is maintained (*fig.* 772.).

* The first, oral, buccal, branchial, or respiratory.
† The second, anal, ventral, or the funnel.

The tests of the little animals of which the cylindrical body of the *Pyrosoma* is composed, are intimately connected by their lateral surfaces, leaving their terminal orifices free (*fig.* 786. A). The tissue of the whole common envelope is semicartilaginous, transparent, tinted with azure and other colours.

In the *Botryllidæ* the external tunic is represented by the tegumentary tissue common to the whole association of animals, and which may perhaps be compared to the polypary of aggregated Polyps. The close aggregation of the animals causes a fusion, as it were, of the tests of the whole into a coriaceous or gelatinous mass, coated with a tough epidermic membrane, and more or less regularly beset with individuals or groups of individuals (systems); or, rather, the soft test of the originally isolated individual, or single system, increasing in bulk and producing within itself more and more embryos of individuals and systems, becomes an extended, homogeneous mass, in which numerous individuals are lodged (*fig.* 771.). This mass is irregular, fungous, jelly-like, spongy, or coriaceous, incrusting other sessile Tunicates and a variety of marine bodies.

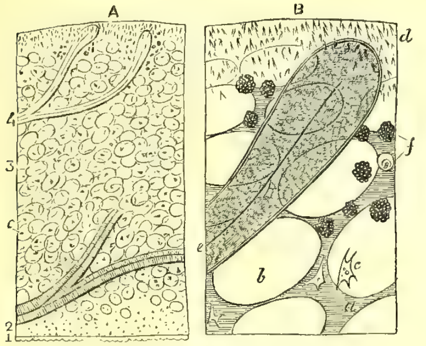
Structure and chemical composition of the test.—We are indebted to the labours of MM. Löwig and Kölliker * for considerable information on the subject of the constituent elements and the growth of the test of the simple and the compound Ascidians. These researches were undertaken with the view of examining into Dr. Schmidt's statement of the existence of the vegetable element "cellulose" in the tissue of the ascidian envelope. This they found to be correct (as the following statements will show), and they have also offered a lucid explanation of the fact, to which we shall subsequently refer. Cellulose forms the cell walls of vegetables, and is unaffected either by soda or hydrochloric acid.

The cartilaginous envelope of *Phallusia mammillaris* (Fam. *Ascidiadæ*), examined in specimens preserved in spirit, is composed of three layers of different thicknesses (*fig.* 773.). The internal layer, formed simply of polygonal, nucleated, epithelial cells, measuring 0·005‴, covers all the interior surface of the test; at the two external orifices, and at the points where it receives the nutrient vessels of the test, it is united with another epithelial tissue covering the mantle. The second layer is considerably thicker, and is composed of a homogeneous substance, containing crystals and nuclei. The former are not present everywhere, and are, perhaps, quite absent in the recent animals; when present they are visible to the naked eye, and appear like white striæ; seen under a moderately magnifying power, they have the form of crystals united in the form of a star, or of irregular and polymorphous concretions. The nuclei are present in considerable numbers and under different forms; those situated towards the interior are round, 0·0015‴—0·002‴, with one or two

* Annales des Sciences Naturelles, 3 sér. tom. vi. 1846.

opaque nucleoli, similar to fat-granules. The external nuclei are larger, round or more or less produced, and contain clear or granular substance, and usually some opaque granules.

Fig. 773.



Test of Phallusia mammillaris.

A. *Transverse section, magnified* 30 *times.* 1, internal layer of epithelial cells; 2, the second or intermediate layer, consisting of a homogeneous mass, thickly strewn with nuclei; 3, the external layer, composed of a fundamental mass and cells of cellulose, with dispersed nuclei (*c*), and having pigment-cells and acicular crystals in the upper part; 4, vessels.

B. *A portion of the same, magnified* 350 *times.* *a*, fundamental mass; *b*, cellulose cells; *c*, nuclei, some round, others star-shaped; *d*, acicular crystals of carbonate of lime; *e*, the extremity of a vessel; *f*, pigment-cells.

The third layer forms the principal mass of the test of this species. It is the seat of the numerous and large arteries, which, arising from the heart, traverse it in every direction, having brush-like ramifications, that penetrate almost to the exterior surface, and then appear to pass into other vessels that accompany them in their course. This layer is formed of large cells, besides a clear homogeneous substance, which is a continuation of the principal substance of the second layer; besides these there are locally distributed crystals, nuclei, and pigment-cells.

The large cells, which R. Wagner previously thought to be cartilaginous, are of a peculiar nature, and resemble no other animal cell hitherto known, except perhaps those of the *chorda dorsalis* of some animals. The most remarkable character of these cells is their size, which varies from 0·008‴ to 0·05‴, the average being 0·02‴ to 0·03‴. Their form is spherical, pyriform, or elliptical; their contents diaphanous and quite destitute of nucleus or granules; and their membrane delicate, smooth, and of an equal thickness throughout.

The smallest cells are irregularly dispersed in the homogeneous fundamental mass that is common to the second and third layers. The larger cells are arranged closely together towards the exterior surface of the layer, presenting a very regular cellular tissue with very little intermediate substance; but, immediately beneath the external surface of the envelope, the cells are rather more distant one from another, and the intermediate tissue more visible. The crystals and pigment-cells before mentioned, are present only in the outer part of this third layer; the former are acicular, about 0·0015‴ in length, occupying in compact masses the intercellular intervals; the latter are yellow, and filled with somewhat large granules, and surround in particular the extreme ramifications of the vessels. The nuclei, lastly, are similar to the large nuclei of the second or intermediate layer, and are everywhere present between the large cells in considerable numbers.

When slices of the test are treated with hydrochloric acid, the crystals of the second and third layers quickly disappear; treated with a solution of *soda*, the epithelial cells, the nuclei, the pigment-cells, and the vessels are dissolved. The fundamental homogeneous substance of the second and third layers and the large cells are *not* dissolved, nor do they suffer any modification.

In *Phallusia monachus* the large cells measure from 0·01‴ to 0·02‴, and are more distinctly separated from one another than in the preceding example. The nuclei of the homogeneous substance are few, and generally fusiform or even ramified; at the external surface of the envelope they are mixed up with a great number of minute yellow pigment-cells and pigmentary granules, as well as with acicular crystals and very minute crystalline concretions; all of these being in the greatest numbers in the neighbourhood of the extremities of the vessels. In one specimen of this species MM. Löwig and Kölliker observed, that in the interior of the third layer no cells could be distinguished; ultimately, however, they distinctly saw well defined cavities or lacunæ, which were evidently vestiges of cells that had been more or less completely fused with the intermediate homogeneous substance; and the traces of these lost cells were found to be more and more distinct towards the band of perfect cells in the surface of the test.

In *Phallusia sulcata* the large round or elliptical cells, without nuclei, have a diameter of 0·01‴—0·15‴.

In *Phallusia gelatinosa* a very peculiar formation was observed by the experimenters. In one specimen the soft, gelatinous substance of the envelope exhibited no trace of cells throughout its thickness, but its mass was principally composed of a homogeneous substance similar to that of the other *Ascidiæ*. In another individual they observed some few and indefinite remains of cells. In both specimens they found, as in the other species, vessels and nuclei, the latter for the most part round and measuring 0·002‴, in the homogeneous substance. In the individual destitute of cells, there was also in the exterior part a very large quantity of acicular crystals and yellow granules, the latter frequently resembling the nuclei with large coloured nucleoli. The tissue in all the *Ascidiæ* examined, when chemically treated, behaved in a similar manner to that of *Phallusia mammillaris*.

We have observed that the test of *Boltenia reniformis* (preserved in spirit) presents a homogeneous structure crowded with "nuclei" and bloodvessels, and only occasionally does any trace of cellular tissue present itself, in which case the cells are very minute, polygonal, and compressed. Mr. J. Quekett has detected calcareous spiculæ in the test of this species. They are situated towards the exterior, and are very numerous and excessively minute. Their form is usually cylindrical, with triradiate or 4–5-fid extremities.*

The composition of the test of *Clavellina lepadiformis* corresponds in all respects to that of the above mentioned *Ascidiæ;* certain parts in the same individual having a more particular resemblance to one species, and others to another. The test, however, is quite destitute of bloodvessels. Transverse sections of the stalk of the *Clavellina* and of the excrescences that spring from it, exhibit a tissue composed of round or elongated non-nucleated cells, 0·01‴—0·014‴, almost destitute of intermediate tissue, and arranged very close to one another.

It is only towards the upper extremity of the stalk that the cells become more and more separate, and even disappear little by little, as happens in some *Ascidiæ*, and give place to an intermediate homogeneous substance, bearing a quantity of nuclei. In the largest and superior moiety of the test a peculiar structure is found. Externally is a dense, but not thick, layer of delicate cells, which are very difficult to recognise, and measure about 0·02‴. Between the cells, and immediately at the surface, are crystals of carbonate of lime, scattered nuclei (measuring 0·002‴), and large round fatty granules. Interiorly to this occurs a still thinner lamina, composed of a transparent, colourless, homogeneous substance, with infinitely minute pale granules. Next, there is a layer of round granules or vesicles. These are spherical, measuring 0·0005‴, 0·0004‴, and even 0·005‴; their surface is smooth or granulated; the largest are placed in the middle, the smallest at the exterior; they appear opaque, and like starch or fat granules. With solution of iodine, they become yellowish, without presenting any trace of blue, and are probably fat grains.

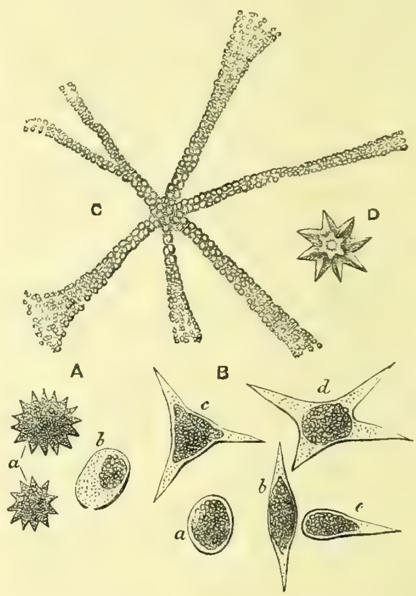
Succeeding to these, a thick layer presents itself, homogeneous, diaphanous, with some few minute spherical nuclei, which, the nearer they approach towards the interior, contain more and more colourless granules. Lastly, quite at the interior surface, is a thinnish, completely diaphanous substance, of equal thickness throughout, with spherical granular nuclei, measuring about 0·003‴.

Treated with soda and with hydrochloric acid, the crystals, nuclei, and fat granules of the test of the *Clavellina* disappear; the large cells, on the contrary, and the homogeneous substance, with its scattered granules, remain perfectly unaffected, proving the identity of the chemical composition in *Ascidia* and *Clavellina.*

* Several specimens are figured by Mr. Quekett in the Descript. and Illustr. Catal. of the Histological Series in the Mus. Royal Coll. Surgeons, 1849, plate xvii. fig. 13.

The *Salpa maxima* does not contain, in its gelatinous envelope, any trace of cells similar to those of the *Phallusia* and *Clavellina.* It is for the most part composed of a homogeneous, clear, diaphanous substance. Towards the interior surface, the several elements are not so clearly arranged as in the middle and external layers. In the innermost layers, a multitude of very minute granules are present; in the others there are little round nuclei, nucleated cells, and spherical or star-shaped crystalline concretions. These latter are very regular, and formed of 3—7 straight rays, springing from a centre (*fig.* 774. c). They

Fig. 774.



A. *Incrusted cells of the fundamental mass of Didemnum candidum. a,* unaltered cells; *b,* a cell the lime of which has been nearly extracted by means of hydrochloric acid. (*After Löwig and Kölliker*).

B. *Incrusted cells of Botryllus violaceus. a,* spherical cell; *b,* cell with two colourless prolongations; *c,* with three; *d,* with four; and *e,* with only one such prolongation.

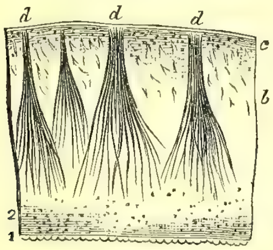
C. *Siliceous concretions from the test of Salpa maxima, magnified* 350 *times.* (*After Löwig and Kölliker*).

D. *Calcareous concretion from test of Leptoclinium maculosum.* (*After Milne-Edwards.*)

are composed of a single or manifold series of granules, which, as they approach the exterior, increase or lessen in number, but always diminish in size. These do not appear to be carbonate of lime, not being soluble in hydrochloric acid; and their behaviour with muriate of barytes shows that they are not formed of sulphate of lime; probably they are siliceous. The granules and nuclei are dissolved by boiling in solution of soda; but the homogeneous substance, composing the mass of the tunic, remains unchanged.

The test of *Salpa bicaudata* is essentially the same, in the nature of its composition, as that of the *Salpa maxima*, the fundamental mass of the gelatinous envelope being composed of the homogeneous substance. It differs, however, in the elements contained in this tissue, and by the presence of a simple layer of epithelial cells, covering it on the interior surface of the test. In the interior layer of the homogeneous substance there are granulated vesicles, having a diameter of 0·003‴ to 0·004‴, sometimes having the appearance of nuclei, and sometimes that of cells. In the middle part, here and there, are scattered round or fusiform nuclei; and in the exterior layer are little crystals, round nuclei, and peculiar concretions, similar to those of *Salpa maxima*. Some of these concretions are small, elegantly ramified, and disposed horizontally; others are larger, ramified in a brush-like form, and appearing to the naked eye as white tufts. These latter commence at the surface, descend vertically towards the interior, and ultimately form a tuft of fine ramified rays (*fig.* 775. *d*).

Fig. 775.



Transverse section of the test of Salpa bicaudata, magnified 30 *times.* (*After Löwig and Kölliker.*)

1, epithelial layer; 2, homogeneous mass, with nucleoli; *b*, fusiform and ramified concretions; *c*, nuclei; *d*, brush-like concretions.

Magnified 350 times, these two sorts of concretions are seen to be composed of opaque granules of different sizes. The chemical composition of the test of this *Salpa* is identical with that of the preceding species.

In the *Pyrosoma giganteum*, the common envelope of the individuals is also formed of a homogeneous and structureless substance. In its interior are scattered here and there round nuclei, and some ramified cells, similar to those of the loose cellular tissue of the embryos of Mammifers, for example, to that of the gelatine of Wharton. Both of these latter elements disappear when treated with soda; but the homogeneous substance altogether resists the action of the soda, and remains intact.

The *Diazona violacea* (Fam. *Botryllidæ*) possesses, in the gelatinous mass of the common test, a diaphanous, structureless substance, quite destitute of cells. In the exterior layers are crystals and concretions of carbonate of lime, vesicles with violet-coloured granules, fat granules, and, particularly towards the interior, a great quantity of minute round vesicles (nuclei). Treated with hydrochloric acid and with soda, the crystals, nuclei, and pigment-cells are dissolved, but the homogeneous substance remains unchanged. Moreover, after having been a long time exposed to the influence of the alkali, and although the pigment-cells have disappeared, some portions of the exterior parts retain a pale violet tint, giving evidence of the presence of undissolved colouring particles, and of an amorphous colouring matter pervading the mass.

The structure of the test of *Didemnum candidum* (Fam. *Botryllidæ*) is quite different from that met with in any of the Tunicates before mentioned. The white substance in which the individual animals are lodged, which has been figured also by Savigny, apparently presents only some white star-shaped bodies (*fig.* 774. A), measuring 0·006‴ to 0·015‴, similar to those found by M. Milne-Edwards, in *Leptoclinum stellatum* and *L. maculosum* (*fig.* 774. D), except only that the former are of a more rounded form, and are provided with shorter and more numerous points.* But, on being treated with hydrochloric acid, this substance has quite another appearance. The white colour quickly disappears, bubbles of gas being freely given off; and, on examination with the microscope, there is seen in the yellowish, transparent membrane that remains, a fundamental homogeneous substance, in which are scattered round and elongated cells, of 0·005‴—0·013‴ in diameter, and some minute granular masses. At first sight these cells appear to be analogous to the large cells found in the tests of *Ascidia* and *Clavellina*, being, like those of the latter, non-nucleated, indistinctly marked by a pale, delicate contour, and having perfectly liquid contents. But by boiling with soda they are quite dissolved, whereas the homogeneous substance remains unchanged. MM. Löwig and Kölliker found also, that under the influence of hydrochloric acid each of the star-like corpuscles showed itself not to be a simple concretion, but, losing its rays little by little, became a cell filled with lime, and ultimately appeared as a colourless, empty cell, quite similar to those above described. They add that they could not discover how these curious cells, filled with lime, and furnished with calcareous rays externally, were formed; but they thought it probable that they were originally large cells, full of liquid, which became gradually occupied with lime, until ultimately the membrane of the cell became incrusted, and the lime deposited on its external surface.

* We have been favoured by Mr. Bowerbank with an opportunity of examining his valuable series of microscopical preparations of ascidian tissues, including several kinds of the spiculæ entering into the composition of the tests. The spiculæ of *Didemnum* are spherical bodies, closely invested with short, thick, blunt spines, and nearly resemble the globular spiculæ of *Tethea*, except that the investing spines of the latter are more numerous and much finer. The tissue occupied by these closely set spiculæ in the *Didemnum* is seen in the transparent portions of Mr. Bowerbank's beautifully mounted specimens to be composed of diaphanous, contiguous, irregularly hexagonal cells, the measurements of which we have not had time to effect. Numerous nucleoli are disseminated throughout the tissue.

The common test of *Aplidium gibbulosum* presents a homogeneous substance with some scattered nuclei, and a great quantity of round cells, with very delicate membranes, measuring 0·005‴ to 0·013‴, and even to 0·02‴. Those in the interior contain only a liquid; but the nearer they approach the exterior, the more are they found to contain calcareous concretions; and, lastly, there are cells perfectly incrusted, but without appendages. Acted upon by soda and by hydrochloric acid, the homogeneous substance alone remains, the rest is dissolved.

In the "common body" of *Botryllus violaceus* are some remarkably incrusted cells, similar in some respects to those of *Didemnum*. Some of these are perfectly round, with a diameter of 0·009‴, and, as those of *Aplidium*, are filled with calcareous concretions; others, for the most part pyriform or fusiform, have one or two pointed, colourless prolongations, 0·006‴—0·009‴ in length, and are organic in substance; others, lastly, round or tetrahedral, have even three or four of these prolongations, which are often of a similar length, and are regularly disposed, but just as often are of different sizes, and without symmetry (*fig.* 774. B).* These prolonged cells are probably analogous to the round cells in *Didemnum*, that have lime in their interior and calcareous deposits externally, and may even be compared with vegetable cells (pollen-granules, spores, &c.), bearing external deposits. Were these cells incrusted, they would form star-like bodies, similar to those of the *Didemnum*.

Professor M. Edwards observes, that in *Leptoclinum* the substance of the tissue is crowded with calcareous granules, which, seen with an ordinary lens, appear to be little spherical concretions, but which are aggregations of little pyramidal crystals, united by their base, so as to represent a many-rayed star, surmounted on each of its faces by a group of other similar, but smaller, rays (see *fig.* 774. D).

The structure of the common test of the *Botryllus polycyclus* is peculiar and quite different from those described above. In the exterior parts of the common mass the structure resembles that ordinarily found in compound Ascidians, being of a clear and homogeneous substance, with some nuclei and crystals; but in the interior distinct *fibres* are found, by the side of the nuclei. These fibres are of two kinds; some, the least numerous, are long, extremely pale and delicate, too fine to be measured, and, crossing one another in all directions, form elegant sinuosities; others, less numerous, are short, 0·01‴ to 0·03‴ in length, larger, opaque, and variously curved; in a word, they resemble certain nuclei transformed into fibres (*Kernfasern*). Like the homogeneous substance of the exterior and interior parts, these fibres resist the action of hydrochloric acid and of soda; and consequently, since they are incontestably organic, they are composed of non-azotised substance.

There are also some round points, visible to the naked eye, dispersed in the common integument of this *Botryllus*. Some are white, generally situated towards the interior of the test, and appear under the microscope as groups of granules or spiculæ; they are insoluble in a solution of soda, or in hydrochloric acid, and are probably siliceous, like the concretions in *Salpa*. The other spots are violet-coloured, or reddish, and are most abundant in the external layers near the groups of individuals, yet sometimes also they are present in the interior parts of the common mass. Seen under the microscope, they appear as pyriform, round, or elongated vesicles, bearing a reddish colouring matter, contained probably in the cells, and are attached to the extremities of the ramifying canals that traverse the mass in every direction. These vesicles are the germs of new individuals.*

The coriaceous test of the *Cynthiæ* (Fam. *Ascidiadæ*) presents a composition still more remarkable than that of the *Botrylli*. In *Cynthia papillata*, the fibres that constitute a large proportion of the test, are in some parts so much developed, that they may bear comparison with the fibrils of any fibrous tissue found in vertebrate animals.

In examining the structure of the test, where it is of no great thickness, we find a simple lamina, quite on the interior surface, consisting of an epithelium, with polygonal cells, which is united to the mantle by scattered, crossing, muscular fibres. A thick layer of fibres succeeds, having cells and nuclei disseminated in it. The fibres themselves are colourless, undulating, resembling the fibrils of the fibrous tissue of vertebrate animals, but narrower; they measure 0·0002‴—0·0004‴ in thickness; they are never ramified, nor united into bundles. In their direction they are in part parallel to the axis of the animal, as in the interior laminæ; and in part differently interlaced, so that some are disposed longitudinally, and others transversely (circular and longitudinal fibres); hence, from the disposition of the two kinds of layers, the test can very easily be split into, sometimes very delicate, laminæ. There is apparently no intermediate substance accompanying the fibres, but the laminæ formed by their divergences are occupied by a quantity of granules and vesicles of different forms. Firstly, there are minute colourless molecules, in some parts so abundant as to render the fibres indistinct, and to give to some of the thicker layers a finely granular aspect; secondly, crystals, which are present only in the exterior layers; thirdly, nuclei, measuring 0·001‴ to 0·003‴, often with large granules, apparently of fat; fourthly, cells of different forms. Some of these cells, containing nuclei

* Specimens of these spiculæ in Mr. Bowerbank's histological collection exhibit much more coarsely granulated centres than those here figured.

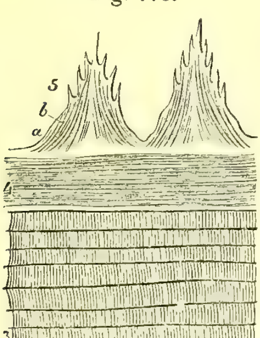
* The epiderm covering the common gelatinous test of *Botryllus stellatus* is very tough, closely adherent, and presents distinct cellular structure.

and brown pigment-granules, are round, having a diameter of 0·005‴ to 0·01‴, or elongated, with a diameter of 0·006‴ to 0·008‴; others are of a pale colour, and, from the double nuclei and the included cells (2 to 7) seen in some of them, strongly resemble the cartilage-cells of the superior animals. This resemblance is rendered the more striking by the round or elongate form of these cells, by the peculiar arrangement of the enclosed cells, and by the union of some of the mother-cells, in this case generally round and smaller, into groups of two or four. This resemblance, however, is only external, and due only to the fact that the cells increase by formation in the interior, as in cartilage; because more exact observations show that these cells, by further transitions, become identical with the simpler pigment-cells described above, and are only the more developed forms of the latter, the pigment having disappeared by degrees on account of the condition of their growth.

The third layer is formed of a yellowish, horny epidermis. The thin hairs which cover the surface of the *Cynthia papillata* are formed by this and the exterior fibrous layer. At certain spots a bundle of fibres springs up from the plane surface of the latter, which, being coated with the horny epidermis, rises on the surface as small needle-shaped bodies.

Where the test of the *Cynthia* attains a thickness of ½ to 1½‴ and more, its composition often changes in a remarkable manner (*fig.* 776.). In this case the epithelium is succeeded

Fig. 776.



Transverse section of Cynthia papillata, magnified 100 *times.* (*After Löwig and Kölliker.*)

1, Internal layer of epithelium; 2, second layer, homogeneous, with pigment-cells; 3, third layer, composed of alternate layers of radiating fibres and fibres parallel to the surface of the test; 4, fourth layer, fibres parallel to the surface of the test; 5, spines; *a*, the thin yellowish outer surface; b, fibrous nuclei.

by a clear, homogeneous, structureless mass, of a moderate thickness, with scattered pigment-cells and nuclei. Next is a fine fibrous tissue, composed of a great number of thin layers of circular fibres, without cells or nuclei, and of radiating fibres that unite these layers; this passes externally into an irregular fibrous tissue, covered with a horny epidermis. Where this peculiar stratification of fibres exists, the test is not separable into laminæ, because the radiating fibres firmly connect the thin layers of circular fibres.

Treated with hydrochloric acid and with soda, the test of *Cynthia* is rendered quite white. The pigment-cells, the coloured epidermis, the mother-cells, the crystals, the epithelium, the nuclei, and the granules are dissolved, and there remain only the fibres and the homogeneous substance that exists here and there. These two elements, then, are composed of cellulose.

The structure of the thick test of the *Cynthia Canopus* is very similar to the above. Interiorly there is an epithelium, then a thick layer of longitudinal and circular fibres, somewhat indistinctly stratified, in which, towards the exterior, crystals and largish round bodies, composed apparently of groups of cells, are disseminated; lastly, a thin layer of solid, whitish epidermis, with little conical papillæ, usually accompanied by processes from the fibrous layer. The thick fibrous layer, only, resists the action of hydrochloric acid and of soda; all the rest is dissolved without any residue.

Cynthia pomaria presents, as the chief material of its test, a layer of fibres similar to those previously described, having chiefly a longitudinal direction. Between the fibres are crystals, round pigment-cells, measuring 0·004‴ to 0·006‴, and further, here and there, peculiar elongated cells, filled with yellow granules, measuring 0·008‴ and more. Internally, and adhering to the fibrous layer, is a simple epithelium, with polygonal cells that have diameters of 0·006‴ to 0·008‴. This adheres to the inner tunic by means of muscular fibres. Externally the fibrous layer is covered by a yellowish, solid layer of undetermined structure. In the interior parts of the fibrous layer occurs a somewhat large number of peculiar cells, apparently not analogous to any other of animal or vegetable structure. These cells are primitively similar to pigment-cells, and round, but possessing a thicker membrane, and without any apparent nucleus. Subsequently they grow, preserving their shape, to the size of 0·01‴. The membrane at the same time continues to thicken, so much so that the cavity of the cell increasing but slightly, the membrane attains a thickness of 0·004‴. Lastly, the size of the cell increases to 0·02‴ and the thickness of the membrane to 0·006‴. Whilst this development is going on, fine lines are observable in the thickened cell-membrane, and ultimately the membrane is transformed into fibres, so that one may see the moderately sized cells in their cavities, and yet occupied by pigment or by pale granules, enveloped with an elegant skein of fine, cylindrical, opaque fibres, which can be isolated by compression. Whether the fibres have a spiral arrangement is uncertain. MM. Löwig and Kölliker, who discovered these remarkable fibre-coated cells, remark that, as to the manner in which this curious transformation of the pigment-cells is brought about, the increase of thickness in the cell-membrane would take place by growth, or by a development similar to that which occurs in many vegetable cells, the membrane of which consists of several layers, or by the deposition of a substance applied externally. As there is no appearance of any internal or external deposit, and as the cell-cavity is not diminished during the thickening of its walls, they consider the first to be the more likely cause of the above conditions, but, nevertheless, not sufficient alone to account for the circumstances. It is difficult, perhaps, to say how these fibres are formed, but it may be that the cell-walls, by partial solidification, ultimately become separable into fibres.

The fibrous tissue of the *Cynthia pomaria* is insoluble in hydrochloric acid, or in solution of soda; the other elements of the test, submitted to these agents, disappear.

The following clever abstract of the facts connected with the subject has been drawn up by Professor Edward Forbes:—

"MM. Löwig and Kölliker found cellulose undoubtedly present in the envelopes of many *Tunicata*, both simple and compound, including the genera *Phallusia*, *Cynthia*, *Clavellina*, *Diazona*, *Botryllus*, *Pyrosoma*, and *Salpa;* but they sought in vain for cellulose in animals of inferior organisation, although in some of the above-named creatures it formed a very considerable part of the animal tissues.

"The Memoir of MM. Löwig and Kölliker was examined by a committee of the French Institute, consisting of Dumas, Milne-Edwards, Boussingault, and Payen; the last-named eminent philosopher drew up the report. In it he gives the following formula of the composition of the envelopes of the *Tunicata:* —

Cellulose - - -	60·34
Azotised substance -	27·00
Inorganic matter - -	12·66
	100·00

"He remarks that the establishment of the existence of cellulose in the *Tunicata* is a 'fait capital' in science, very important in its bearing on future researches into the comparative physiology of the two kingdoms.

"The explanation offered by Löwig and Kölliker of these very anomalous facts is extremely ingenious, and probably very near the truth. It is to the following effect: — *Tunicata* live entirely upon vegetable organisms. The contents of the stomachs of the *Phallusiæ*, *Clavellinæ*, and *Diazonæ*, examined, consisted of particles of florideous algæ, which had probably found their way there by chance, and a great quantity of microscopic plants of low position in the series, species of *Navicula*, *Frustulia*, *Baccilaria*, *Closterium*, &c. These minute vegetable organisms have been shown by Nageli and Schmidt to contain cellulose.

"This is probably dissolved by the gastric juice, that is to say, changed into sugar or gum, in which state it circulates with the blood, and is afterwards introduced into the tunics, either directly by the sanguiferous canals (as in *Phallusia*), or by their prolongations ramified in the walls of the common body (as in *Diazona* and *Botryllus*), which thus, as Milne-Edwards has shown, contain also blood in their cavity, probably penetrating by imbibition when the envelopes have no bloodvessels. The presence of cellulose in the tunics of the ascidian Molluscs, then, cannot be taken as an evidence of an approach to a vegetable nature in those bodies. It affords us, however, a wholesome warning against the placing of confidence in asserted chemical distinctions between the great kingdoms of Nature." *

From the observations made by MM. Löwig and Kölliker on the histological characters of the embryos of certain compound Ascidians, they arrived at two important results. Firstly, that the external structureless envelope of the embryos, which, apparently, is identical with the external envelope of the adults, is, according to their analysis, composed of cellulose; that this envelope is formed only when the division of the yolk is accomplished, and even when the exterior form of the embryo is indicated. Secondly, that this envelope, subsequently containing, as in *Botryllus* and in *Aplidium*, another structureless substance, fibres, nuclei, and crystals, is primitively altogether *homogeneous* and *unorganised.*

Hence it appears that the test of the Tunicates is a product of the activity of cells formed subsequently to the process of the division of the vitellus, and that primitively it is only a mass secreted by these cells. Its ulterior organisation is not yet understood, but remains an open field for much interesting and important research.

Anatomy of the Ascidiadæ.—We have already referred to the external envelope of the Tunicates as being analogous to the calciferous shells or tests of the other Acephalans; and the muscular sac enclosed within it, as the analogue of the mantle; and the membranous sac lining the mantle as analogous to the branchiæ of the Acephalans.†

The rest of the viscera of the Ascidians are enveloped in a peritoneum‡, and the heart has, besides, its own membranous sac or pericardium. Thus the body, properly so called, appears as if divided into three cavities; that of the branchiæ, communicating with the exterior by the superior opening of the sac,

* Hist. Brit. Molluscs, vol. i. p. 6.

† According to Van Beneden, the longitudinal vessels of the branchiæ of the *Ascidiæ* are more particularly the analogues of the ciliated tentacles of the *Bryozoa.*

‡ The peritoneum of *Ascidia intestinalis* offers a good example, being of firm consistence, circumscribing and protecting the abdomen.

and in the base of which opens the mouth; that of the peritoneum, which does not communicate with the exterior by itself, but is traversed by the intestinal tube, which, arising in the branchial cavity, communicates with the exterior by the rectum and the anal aperture of the test; and, lastly, that of the pericardium, which has no direct communication with the exterior.

The position of the animal is always such, that of the two orifices the branchial is always the highest; the entrance into the branchial sac being generally placed at or near the superior extremity of the body, and the œsophageal opening, at the base of the branchial sac, having an upward direction. In *Boltenia* and *Cystingia* the flexible peduncle, which is attached at the summit of the body, above the branchial orifice, allows the body to droop, thus giving the animal its normal position. In the *Clavellinidæ*, which have rigid peduncles continuous with the base of the test, the same normal relation of the internal parts is preserved; and although the intestinal loop in *Boltenia* and *Clavellina* is always directed towards the pedicle, yet this arises from the loop having, in the former an ascending, and in the latter a descending, direction.

The *muscular sac* or *mantle*, enclosed in the external envelope, is attached to the internal surface of the latter by an adhesion of the external surface of the extremities of its two tubular processes, which correspond to the two external orifices of the test, to the inner borders of these outer orifices (*fig.* 780.). In *Ascidia* there is often no intimate cohesion at these points, merely an adaptation easily disturbed after death. In *Cynthia*, *Boltenia*, &c., on the contrary, the test and the tubular prolongations are strongly adherent. Beside this mode of attachment, there is sometimes a general loose adhesion formed by the epithelial tissue between the surfaces of the test and mantle; and in *Cynthia papillata* there is a partial transmission of muscular fibres from the latter to the former; and, lastly, there is the very slight attachment arising from the passage of bloodvessels from the body to the test.

This free condition of the mantle within the external sac occurs throughout the *Ascidiadæ*, *Clavellinidæ*, *Botryllidæ*, and *Pyrosomidæ*. In the *Salpidæ* and the *Pelonaiadæ*, on the other hand, the mantle and the test are connected at very many points, or even throughout the extent of their contiguous surfaces.

The mantle in *Chelyosoma* is more closely attached to the internal surface of the test than in other Ascidians; its muscular tissue forming intimate connections between the various plates of the external envelope, and not only supplying the valvular pieces of the apertures, but also edging each of the larger plates with interlacing connecting fibres. Except at these muscular spaces the mantle appears as a thin serous membrane.

The interval between these two sacs is, during life, filled with some fluid; possibly a secretion, or transudation through the one or the other of these envelopes; for, except in the case of those Ascidians whose mantle-tubes are not intimately connected with the test, the sea-water cannot be directly admitted into this cavity.

The mantle is reflected upon the body, properly so called, and covers it externally, just as the peritoneum, after having coated the walls of the abdomen, is reflected upon the intestines; with this difference, however, that it has no mesentery, and that the connection is only at the two orifices. It has an external serous layer, continuous with the internal membrane of the test, a muscular tissue more or less extensive, and an internal serous layer. It has also numerous ramifications of nerves and bloodvessels. In *Boltenia*, *Cystingia*, and probably *Bipapillaria*, a tubular prolongation of the mantle traverses the peduncle.

The two tubes on the superior aspect of the mantle, which are directed towards, and protruding into, the two somewhat tubular orifices of the test, are more muscular than the rest of the sac, being surrounded with, generally very distinct, sphincters in addition to the fascicles of muscles that traverse them longitudinally, and are continued diagonally across the sac (*fig.* 780.). When open, the margins of these tubes are crenulate. The free extremity of the branchial orifice is sometimes quite entire, but occasionally terminates in a circle of regular tooth-like processes, which are regarded by Dr. A. Farre as the analogues of the tentacles of the Bryozoa. By contraction, the tubes are thrown into 5 or 6 folds. At the exterior angles of these folds in some Ascidians (*A. intestinalis*, *Cynthia ampulla*, &c.) there is a minute red spot; in *A. mammillata*, the edges of the folds are more or less reddened by an increase and diffusion, as it were, of these little red granules. Internally each tube has frequently at its base some slight valve-like prominences or folds; and the inner extremity of the branchial tube is always fringed with a circlet of simple or compound tentacular filaments. These, however, may more properly be said to belong to the branchial sac.

The mantle becomes dusky and opaque, and its muscular tissue more distinctly seen, in preserved specimens. In its recent state it is more or less diaphanous, and usually of a sober tint; but occasionally, in *Ascidiæ*, it is of a fine crimson (*A. venosa*), or variegated with crimson and white (*A. virginea*), or spotted with red (*A. aspersa*); and in *A. parallelogramma* it is ornamented with rectangular reticulating white lines and occasional bright yellow or crimson spots. In *A. conchilega* it is white, passing to blue; and in *A. arachnoidea* it is dark blue.

The *branchiæ* of the *Ascidiadæ* is a large bag of fine vascular network furnished with vibratile cilia, contained within the mantle of the animal, and lining the walls of that cavity (*fig.* 778.). Sometimes the branchial sac is oblong, oval, or rectangular; and then it occupies all the length and one of the sides of the cavity of the mantle (*Cynthia*). In *Ascidia mammillata* and *A. monacha* it is very long; and, after having descended to the bottom of the mantle, it is bent upwards upon itself, extending half way up the cavity again.

A tube, differing in size in various species, which has its analogue, perhaps, in the retractile operculum of the *Bryozoa*, conducts the water from the buccal aperture to the respiratory sac. This tube or process of the mantle encloses the neck of the branchial sac. At the inner extremity of the tube, where it widens into, and is continuous with, the branchial sac, are frequently observed about five small valvular folds; and below these there is always a circle of fleshy filaments or tentacular appendages (*fig.* 778. and *fig.* 39 *d.* Vol. I. page 112. ANIMAL KINGDOM*). These are present also in the *Clavellinidæ* and the *Botryllidæ*. They vary from 6 to 26 in number, and are either simple, as in *Phallusia*, or branched, as in *Cynthia*, *Boltenia*, &c. By detaching the anterior part of the respiratory sac of *Cynthia*, or others, and examining it from its inner and inferior aspect, one may perceive, at the inner margin of the tube, several arboriform appendages, somewhat large at the base, and having the branches either swollen at their extremities, or finely laciniate and almost plumiform: in *Cynthia Dione* they are somewhat bipinnate. The number of the tentacles is difficult to be arrived at, as smaller filaments appear amongst the six or seven larger ones. The branches are generally directed downwards, towards the bottom of the sac, but sometimes are slightly curled upwards. Seen under the microscope, these filaments are hollow; and the extremities and swellings of the branches are cul-de-sacs. The several tentacles intercommunicate with each other by their hollow bases, and with the vascular network of the respiratory sac.

The walls of these tubular organs are very thin and transparent; traces of muscular fibre have been detected in their substance, and a circulation; but no trace of vibratile cilia, either on their outside or within their cavity. Van Beneden observes that a fluid traverses their cavity in a similar manner to the blood in the branchiæ of the *Doris*. In *Actinia* and *Holothuria* simple and ramified filaments occur, that offer considerable analogies to the arborescent tentacles of *Ascidiæ*. They are all hollow; and the fluid moving in their interior comes directly from the peri-intestinal cavity; this great cavity, communicating as in *Bryozoa*, with the tentacular appendages.

The internal surface of the respiratory sac is sometimes uniform (in *Ascidia*, *Phallusia*, &c.), and frequently longitudinally plicated and disposed in deep and regular folds, all following the curve of the cavity, and terminating at a little smooth area above the pharynx (*Cynthia*, *Boltenia*, &c.). The folds are from 8 to 18 in number, and form the first indication of the four branchial laminæ of the bivalve Acephalans. The structure of the membrane consists of an infinity of small, anastomosing vessels, generally crossing each other at right angles, and forming quadrangular interspaces, which, under the microscope, are seen to be still more minutely subdivided in the same manner. Milne-Edwards observes that in *Phallusia* each of the meshes of the respiratory membrane is occupied by a minute spiracle, that allows of a communication between the interior of the branchial sac and the cavity of the mantle (the "thoracic chamber" of Milne-Edwards), the dorsal portion of this chamber being the cloaca, the base of which is occupied by the orifices of the digestive and generative tubes, and the summit of which opens externally by the anal aperture. In *Cynthia ampulla* the meshes are very irregular and almost inextricable, some of the minute vessels having apparently a spiral arrangement; and the vessels are rather more numerously disposed around the œsophageal orifice. A somewhat spiral or vermicular arrangement of the extremities of the branchial vessels exists also in *Chelyosoma*, as figured by Eschricht;* and as seen in a very minute sessile *Ascidia*, from South America, in the collection of Mr. Bowerbank. In the respiratory network of *Cynthia* the large longitudinal vessels are seen to be the most prominent of all. They form, with the large transverse vessels, square meshes, which three other shorter vessels subdivide into four transverse meshes; and these are further intercepted by extremely fine longitudinal vessels. The vertical vessels of this quadrangular network may be said to arise from the transverse vessels, which communicate by each extremity with two vertical trunks, placed at opposite sides of the sac, and representing respectively the branchial artery and vein. The latter, in *C. microcosmus* and other Ascidians, bears a longitudinal series of small transverse tentacular filaments. Similar tentacles we shall have to describe as belonging to *Chelyosoma* (*fig.* 777. *i*).

The angles of the meshes of the branchial tissue bear papillæ, more or less prominent, in some genera (*Ascidia*, *Chelyosoma*, &c.); but in others they are not papillated (*Cynthia*, &c.). These papillæ, or minute pouches, are, according to Savigny, analogous to the filaments that border the branchial vein, in most of the simple and compound Ascidians, indicating the junction of the transverse vessels with that vein. The appearance of the reticulation is large and coarse in *Cynthia*, minute in *Ascidia*, and indistinct in *Cystingia*.

Each mesh of this respiratory network is thickly fringed with vibratile cilia, as in the rest of the Tunicates and Acephalans; and Van Beneden points out that this ciliated exterior of the branchial vessels is analogous to the ciliated tentacles of the *Bryozoa*. By the

* This figure represents a *Cynthia canopus* cut open; *a*, œsophagus; *b*, stomach; *c*, anus; *d*, external anal orifice, closed; *e*, branchial orifice, laid open; *f*, branchial tentacles; *g*, nerve-ganglion; *h*, dorsal sinus; *k*, ovary (?); *i*, *l*, indeterminate bodies.

* Roy. Danish Transact. vol. ix. pl. 1. fig. 6 & 7.

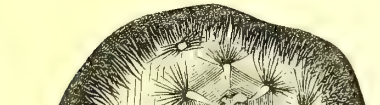
action of the cilia the currents are sent in the direction of the œsophageal aperture.

In *Ascidia papillosa* and *Cynthia microcosmus*, a little soft tubercle is situated on the interior of the branchial sac, not far from the orifice, between the two branchial veins, not observed in other Ascidians, but seen in all the Botryllians. On the internal surface of the sac are also seen several prominent lines, 12–15 in *A. mammillaris* and *A. papillaris*, 5–6 in *C. ampulla*, more or less distant from one another according to their length. These are folds forming gutters converging towards the mouth, and having also transverse channels leading from one to another. Above they appear to terminate in culs-de-sac. The vibratile cilia covering them are very long and numerous.

Van Beneden found that, on placing for a short time a living Ascidian in water coloured with carmine, the particles of the colouring matter quickly filled these little ducts, making them appear like injected vessels. This distinguished naturalist considered them to be somehow connected with the digestive apparatus, moulding, perhaps, the particles of food into cord-like masses before entering the stomach.

In *Chelyosoma* (*fig.* 777. *i*) there is a remark-

Fig. 777.



Anatomy of Chelyosoma Macleayanum. (*After Eschricht.*)

The inner or under side of the superior plated surface of the animal is shown, the branchial cavity being split open, and the abdominal viscera removed. *a*, branchial orifice, partly closed by a membrane, and surrounded by its hexagonal sphincter muscle and the accompanying six fan-shaped muscles; *b*, anal orifice, similarly provided with muscles; *c*, *c*, muscles bordering the carapace-plates; *d*, the central hexagonal plate; *e*, *e*, *e*, *e*, the surrounding plates; *f*, the nerve-ganglion and nerve-fibres; *g*, *h*, the auditory apparatus (?); *i*, the row of tentacles anterior to the œsophagus; *j*, stomach; *k*, part of the intestine.

ably large row of simple tentacles running from the interior of the branchial orifice to the entrance of the œsophagus, and closely connected with the branchial tissue, as in *Cynthia microcosmus*, &c. They appear to surmount a longitudinal vessel or duct, possibly the branchial vein; they are about 23 in number, and have a transverse direction towards the left side. The posterior tentacles are the largest, of about a similar size to the tentacles of the branchial orifice; the others, towards the anterior extremity of the row, become gradually smaller. Their use is not very evident; possibly they are connected with the organs of digestion; but, more probably, they are auxiliary respiratory organs, like the circlet of tentacles within the branchial tube.

The respiratory cavity, in addition to its external or oral orifice and its œsophageal aperture, presents also, in some cases at least, a lateral opening, first noticed by Carus*, and since by Van Beneden. The presence of this communication allows the water, received into the branchial sac for respiration and the conveyance of food, to pass directly out by the anal aperture. Otherwise, when no such communication exists, the water must be ejected through the oral aperture by muscular contraction, as in the *Acephala*.

In *Clavellinidæ* and *Botryllidæ* the open meshes of the respiratory network†, or branchial stigmata, also allow of the free passage of water from the respiratory cavity to the cloaca. In *Pyrosoma*, *Pelonaia*, and *Salpa*, the disposition of parts admits of the free passage for the water from the one external orifice to the other.

Externally the branchial membrane presents very similar appearances to its net-like interior surface: where folded, however, of course the folds and sulci are reversed. It is attached more or less firmly to the inner surface of the mantle on the one side, and on the other to the intestines, stomach, and ovaries, by transverse, short, delicate, perhaps vascular, threads, one of which proceeds from each angle of the meshes.

"In the young Ascidian," says Carus, "the respiratory sac can be distinctly recognised as an integral part of the intestinal canal. As the body increases, this originally crop-like dilatation gradually attains a more considerable extent, and differs in structure from the intestinal canal in having exceedingly delicate and transparent parietes; in a word, diverging more and more from the intestine."

We may further observe, that the vertical vessels entering into the composition of the framework of this branchiferous pharyngeal sac, and representing, according to Van Beneden, the tentacula of the *Bryozoa*, are not only analogous to the latter in their respiratory function, but are subservient also to the purposes of alimentation, like the tentacles

* Meckel's Archiv f. Physiologie, B. ii. l. 4.

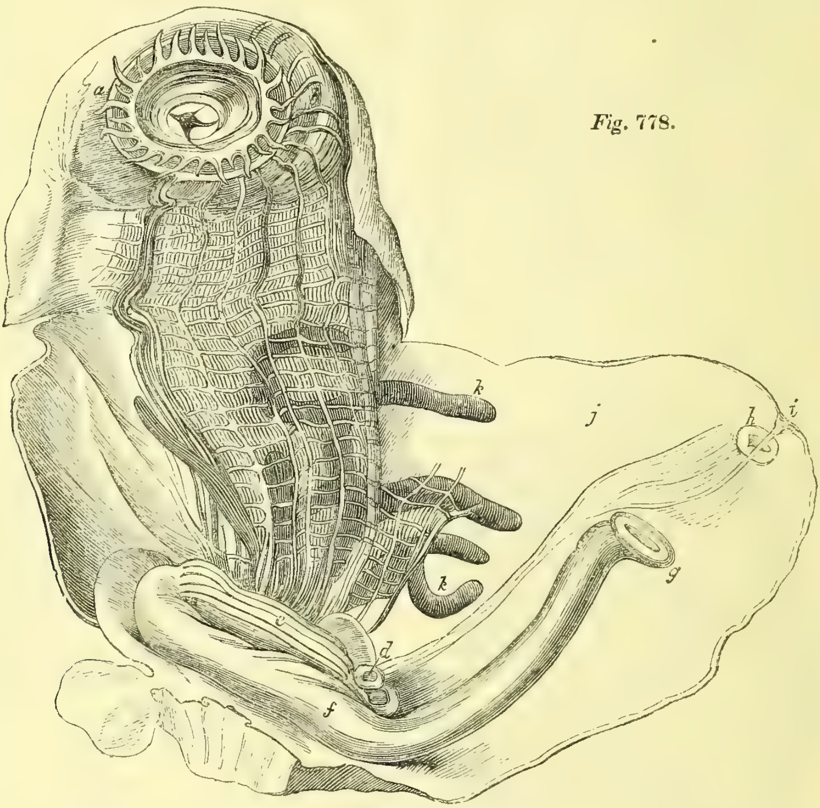
† M. Coste (Comptes Rendus, vol. xiv. p. 182. 1844) denies the existence of open stigmata.

referred to, by producing, and being traversed by, the ciliary currents that bring the food to the œsophageal aperture; and that the tentacula of *Bryozoa* are essentially members of the alimentary apparatus is shown by the fact, that animalcules, &c. are frequently caught and detained by the action of the tentacles, one or more of which, and sometimes even the whole, bend suddenly inwards, and secure such particles as come within their reach, thus taking the character of prehensile labial or oral appendages.*

The cavity of the branchial sac is often the habitation of parasitical Entomostraca.

The buccal or branchial orifice of the Ascidians terminates, as we have already noticed, by a valvular opening in the large delicate membranous sac, which in some respects appears to be a kind of crop, and in others a respiratory cavity. Opposite to it, and in the lower part of this cavity, is the commencement of the œsophagus (*fig.* 778. *d*), which leads to the stomach and thence to the intestine. The viscera are always more or less

Fig. 778.



Anatomy of Dendrodoa glandaria, magnified about 3 *times.* (*After MacLeay.*)

a, summit of the test open and thrown back; *b*, upper part of the branchial sac opened and thrown back with the test, so as to expose its inner surface and the circlet of tentacles surrounding the inside of the branchial orifice; *c*, the ventral sinus; *d*, œsophageal aperture; *e*, stomach; *f*, intestine; *g*, anus; *h*, inner aspect of the external anal orifice; *i*, nerve-ganglion, situate between the two external orifices, and cut through in opening the animal; *j*, part of the test or external envelope; *k*, *k*, branched ovary, single, and on the left side.

lateral, except in *Chelyosoma*, where they are disposed flatwise, below the branchial sac. The convolutions of the intestine are placed between the respiratory sac and the muscular envelope or mantle, and are either unattached, except by slight filamentous processes arising from the external surface of the branchial sac, or buried in the substance of the liver and ovaries.

* Mr. A. Hancock, on the Anatomy of the Freshwater Bryozoa, Annals and Mag. Nat. History, 2d series, vol. v. p. 176. See also Lister and Farre, loc. cit.

The *mouth*, or *œsophageal orifice*, is at the base of the branchial sac; so that when the latter extends to the bottom of the cavity of the mantle, the mouth is also at the base of the mantle. When the branchial sac stops short at the middle of the muscular sac, or when it is bent upon itself, the mouth also is near the middle. In the species that have an oblong, transverse cavity, the mouth is at the postero-inferior angle of the branchial sac. The mouth is either a simple round hole or a slit, or it is an aperture divided up by slight folds or ridges. It is always destitute of lips or tentacles, unless we except the peculiar longitudinal row of tentacles passing forward from the œsophageal aperture along the wall of the branchial sac in *Chelyosoma* and other genera. The œsophagus, sometimes obsolete, is always very short, and is more or less plicated longitudinally.

The *stomach* is simple, generally merely a slight dilatation of the alimentary tube (*figs.* 777. *j*, and 778. *e*). In *A. mammillata* it is strongly plicated, and the pyloric extremity narrowed by little fleshy papillæ. It is sometimes bent upon the intestine and adherent to it, and is often enveloped in the liver, with which it is intimately adherent. Its walls are very unequal, internally forming various lacunæ, through which the bile penetrates, as in the Bivalves; the little bile-ducts are guarded with valvules. In *Boltenia reniformis* the stomach is destitute of any internal folioles or lacunæ; but in *Ascidia intestinalis*, *Cynthia papillata*, *C. canopus*, and others, internal plicæ are present; and in *C. ampulla* the stomach is almost filled up with longish folioles, and is of a light yellow colour from numerous yellowish granules contained in its tissue.

In *Dendrodoa* the stomach is striated externally (*fig.* 778. *e*). In *Cystingia* it is very large, extending almost the whole length of the body, and bears externally a deep longitudinal depression, and is marked internally with faint transverse striæ. In *Cynthia polycarpa* and *C. pomaria*, a little cœcum occurs just anterior to the pylorus.

The *intestine* is usually short, simple, and without cœca. In several species of *Ascidia* its internal surface is traversed throughout nearly its whole length by a semicylindrical, hollow, ridgelike plication, the "intestinal rib" of Savigny, having the appearance of an invaginated intestine. In its course, the intestine generally makes one or two folds. Its walls are thickened frequently by a glandular tissue, probably supplying some fluid necessary to digestion; and its internal surface sometimes bears biliary lacunæ. The rectum leaving the peritoneum floats unattached, and opens opposite to the second or anal orifice of the mantle, so that the excrements falling into the cloacal cavity are carried away by the current of water leaving the body. In the stomach and intestines is usually found a mass of finely divided matter, chiefly, if not wholly, derived from diatomaceous plants. Towards the posterior extremity of the intestines the excrements are usually moulded into little earthy-looking filaments, as in most of the Molluscs. The fæces appear to be formed into these vermiform cords in the sulcus along the side of the longitudinal intestinal fold.

In *A. mammillata* the duodenum has several slight transverse striæ. In *Cynthia ampulla* the intestinal walls are internally hollowed into lacunæ and little folds, which, like the coats of the stomach, pour out a yellowish fluid like bile. In *Dendrodoa* the intestine is of considerable length. In *Boltenia reniformis* also the intestine is long, mounting up as high as the base of the pedicle, then descending nearly parallel with itself and terminating in an ascending conical rectum, the anus having a scalloped margin. In this species there are twelve subcubical bodies, separate from each other, adherent to the upper and inner surface of the rectum, having the free edge of a part of the ovary between them and the liver. In size they differ among themselves, the largest lying towards the anus, and the smallest in the opposite direction; they have no apparent communication either with the intestines, with each other, or externally. Under the microscope their structure appears to consist of a very fine homogeneous colourless membrane, enclosing an infinite number of excessively minute nucleated cells, readily separable from the tissue, which have much the appearance of blood globules. In *Chelyosoma* the digestive apparatus is large, and, from the shape of the animal, is arranged flatwise. The œsophagus commences at the posterior left corner of the branchial sac, between the two chambers of the heart. Advancing obliquely forwards, it enters the stomach, around which are clustered the biliary cœca. The intestine goes on to make a single bend, and, coming back to the left posterior corner, proceeds towards, and terminates abruptly at a very short distance from, the anal orifice.

The *liver* of the *Ascidiadæ* generally occurs in a very degraded form; it is either absent, as in *Ascidia*, *Dendrodoa*, and some *Cynthiæ*, or its place is supplied by lacunæ and folioles on the inner coats of the intestinal canal, occurring, in *Cynthia ampulla*, both in the stomach and duodenum; or, on the other hand, it is more or less amply developed, as in *Boltenia*, where it appears as an irregularly lobulated body, coating the stomach externally behind the right ovary, and passing from the lower extremity of the body, half-way up, in the cavity of the mantle. The lobes differ in size: the largest are placed towards the pyloric or highest end of the stomach, and are more distinctly separated from each other than the smaller ones; they are more or less rounded and granulated, their surface being minutely papillated and composed of minute round bodies, at first sight resembling ova. In *Cynthia* the liver is greenish, granulated, foliated, or, as in *C. Dione*, caniculate. It is sometimes formed of clustered groups of flask-shaped cellular bodies, the individual cells being fixed by their larger ends, and having a radiate arrangement. It is intimately adherent to the external surface of the stomach, which frequently is totally enveloped by it. The bile enters the stomach by distinct holes at the bottom of the cavities of the little lacunæ before-mentioned. In *C. microcosmus*, and others, the liver is divided into masses, one of which is situated on the left of the branchial sac and quite free of the abdomen. The liver in *Ascidia intestinalis* has the appearance of somewhat salient glandular bodies, situated as well on part of the intestine as on the stomach. In *Chelyosoma* this organ is represented by a cluster of short cœcal tubes lying all over the external surface of the stomach. The liver cells in *Boltenia* are elongated cœca, thick, and sometimes deeply divided at the outer extremity, attached by their thin ends, and arranged in eccentrically radiated groups, enclosed in an epithelial membrane, the whole having externally a racemiform appearance.

The digestive organs of the *Tunicata* are subject to congenital malposition ; of which M. Savigny has described two remarkable examples, in *Cynthia Momus* and *Phallusia Turcica;* and Mr. MacLeay was inclined to regard as a malformation a peculiar arrangement of the intestinal canal that was presented by the unique specimen of *Cystingia Griffithsii* described by him. In a unique specimen of *P. Turcica,* examined by M. Savigny, the intestine lay to the left instead of the right of the branchial sac, and was found bending backwards and embracing the stomach from below, instead of bending forwards at some distance from the pylorus, approaching the superior border of the stomach, and then terminating in the rectum. In a specimen of *C. Momus,* the alimentary canal was also found on the left-hand side ; but, by a very peculiar introversion, the pharynx was placed at the posterior instead of the anterior extremity of the branchial sac. The intestine descended as far as the bottom of the mantle, folded itself forward, and ascending parallel to itself, terminated opposite to the pharynx ; so that the anus and the œsophageal aperture both opened into the branchial orifice. The external communication through the anal orifice existed as usual. Both of these malformed individuals had their ovaries full of eggs, but were not, apparently, in strong health, and were more than usually infested with entomostraca. In the catalogue of the Hunterian Museum (vol. i. pl. 5. *fig.* 2.), a dissection of an Ascidian is figured after a drawing by John Hunter (the original specimen, however, has not been found), in which there is, apparently, an abnormal elongation of the oviduct, which is accompanied by a slight granular line, both lying on a large tapering tube having much the appearance of intestine; the anus, however, shows itself projecting from the side of this tubular body some way lower down, in its usual place. The oviduct, and, apparently, the accompanying elongated tube, terminate externally at a minute aperture placed in the sulcus between the two projecting terminal orifices of the test. The oviduct, however, barely reaches this aperture ; and its accompanying granular line terminates still lower down.

Organs of circulation. — In the *Ascidiadæ* there are two large vessels or sinuses, the dorsal and ventral, to which the branchial capillaries, on the one hand, and the heart and peri-intestinal cavity, on the other, are intermediate. The circulation is of the mixed or reptilian type ; both sinuses being in connection with systemic and respiratory capillaries, and the blood, consequently, being sent by one impulse both to the system and to the branchiæ, and ultimately returning from both by the same channel. We are prevented from calling either of these sinuses arterial or venous, on account of the periodic reversal of the circulation, mentioned incidentally above, and more fully detailed hereafter, whereby they are alternately changed from vein to artery and from artery to vein. One of the branchial trunks, terminating at the heart, however, answers to the branchial veins of the Gasteropods and Bivalves ; the opposite, and often double, trunk may therefore be looked upon as the branchial artery, and is connected with the veins of the body. The *Ascidia,* like the rest of the *Acephala,* has but a left or aortic ventricle, and no ventricle at the union of the vena cava and the pulmonary artery. This aortic heart or ventricle is not always easy to be seen. When the branchial sac is simply oblong, it is situated towards its base ; and consequently, when the branchial sac is as long as the body, it is situated towards the base of the mantle; and when the sac is shorter than the body, it is placed near the centre of the mantle. When the branchial sac is bent upon itself, the heart is situated at the curve, and then it is always near the middle of the body. In general its position, according to Cuvier, appears to be determined rather by that of the mouth, than that of the rectum; but M. Milne-Edwards and Van Beneden consider that it follows in its displacement the organs of generation rather than the mouth. The heart in the *Tunicata* is never traversed by the rectum, as in other *Acephala.*

In the Ascidians the form of the heart is oblong, and thin at the two ends, or more or less tubular. Its substance is contractile, but extremely thin and transparent, so that it is scarcely distinguishable in the cavity of its highly pellucid pericardium. Cuvier observed that, in the species in which the branchial sac is bent upwards, he was not able clearly to discern a dilatation sufficiently marked to deserve the name of a heart, and was inclined to think that possibly in this case the heart's function was performed by the artery. Here, however, we may notice that specimens preserved in spirit generally afford but very indistinct traces of this organ; and Cuvier does not appear to have had the opportunity of studying transparent specimens of the living animal, in which the heart can be detected by its pulsating movements.

In *Ascidia intestinalis* the heart, which is very long, and extended under the ventral border of the respiratory sac, communicates with the great thoracic sinus by a longitudinal slit situated at a little distance from its anterior extremity ; and when the peristaltic movements of the heart advance from behind forwards nearly all the blood contained in its cavity passes into this sinus, penetrating the vascular network of the branchial sac, and passing into the dorsal sinus, whence it is spread amongst the viscera, and returns to the posterior extremity of the heart not far from the anus. During this time the heart consequently performs the functions of a branchial ventricle, and the great thoracic sinus is a kind of pulmonary artery. But when this state of things has lasted some minutes, the direction of the peristaltic movement of the heart is inverted, and the blood, instead of traversing the branchial network from below upwards as previously, moves from above downwards, and passes from the great thoracic sinus into the heart. The latter is then an aortic ventricle, and the sinus a branchial vein or aortic auricle. In a very fresh and uninjured individual, of *Cynthia ampulla*, Van Beneden counted 45 contractions in one direction; and then, after a rest during the space of two pulsations, he counted 160 to 170 in the other, the pulsations being about 70 per minute.

In injecting the vascular system of the simple Ascidians, M. Delle Chiaje thought he found certain valvules so disposed as to hinder the return of the blood from the aorta into the cavity of the heart, or from passing again from the heart into the vessels through which it had arrived there. But by careful observations on living specimens, both Milne Edwards and Van Beneden have established the fact, that, as in the *Botryllidæ*, the *Salpidæ*, and the other Ascidian families, the blood of the *Ascidiadæ*, after having flowed for some time in one direction, traverses the same circle in an opposite direction; a condition that would be impossible were any valvular hindrances to return currents of the blood present.

In *Chelyosoma**, the heart is very distinctly seen in the animal when dissected; it lies near the œsophagus, and has two distinct chambers. The aorta rising from its anterior part is a stoutish vessel, and at first lies close to the intestine: it afterwards runs in the space within the intestinal loop, ultimately breaking up into largish branches, distributed on every side. The ramifications divide some 4 or 5 times, and terminate somewhat abruptly, the extremities appearing as if closed. Throughout the surrounding generative organs there is a very fine network of vessels, but whether they are arteries, veins, or gland-ducts is undecided. A largish vessel running along the left side of the stomach and duodenum appears to return the blood to the branchial sac.

Mr. MacLeay describes the heart of *Cystingia* as being large, ovoidal, and of a lobular appearance; and having four vertical, lateral openings, capable of considerable dilatation.

In *Cynthia ampulla* the heart is placed a little within the great intestinal loop, and near the middle of the body: it is fixed on an oblong vesicle, enclosing calcareous concretions. This vesicle is situated exterior to and above the first or principal bend of the intestine. Its colour is a greenish yellow, and it has apparently no aperture, or communication with other organs. The heart itself is a slightly bent tube, with very elastic walls: it has two openings; a single large aperture on one part, and opposite to it three vessels that carry off the blood in different directions.*

"The circulation of the Ascidians," says Van Beneden, "differs but little from that of the *Bryozoa;* and is transitional between that of the Polypes and of the Molluscs. If we remove the heart of the Ascidian, the disposition of parts is very similar, and the simplification of an apparatus cannot more visibly take place. The Ascidia is but a digestive canal suspended in the midst of external membranes, with a liquid moving in the peri-intestinal space. A colourless liquid (blood) occupies this cavity; but it is only in the branchial network and tentacles that it can be said to be contained in vessels. All around the intestinal tube this fluid is alternately moved from right to left, and *vice versâ.* In the vessels composing the vascular network, and in the respiratory tentacles, the same movement of the nutrient fluid takes place. This blood contains somewhat regular globules, white as the containing liquid, that indicate the course of the fluid. In some individuals the blood is yellowish. M. Milne-Edwards has observed an Ascidia with red blood."† Mr. Lister observed that in a sessile Ascidian half an inch long, the blood-globules were about the same size as those of the minute *Perophora*, viz. from ·00025 to ·0002 inch in diameter.

Van Beneden, to whom we are indebted for so much information with regard to simple Ascidians in general and *Cynthia ampulla* in particular, has observed in living specimens of this species, that the blood is distributed to each branchial trunk at the same time, and with the same direction, ascending and descending alternately. According to this, the heart, contracting in one direction, sends blood towards the branchiæ, filling all the vessels at one time, and recalls it by contracting in an opposite direction. That a series of contractions in one direction, during a certain time, may take place without engorgement, there must be a direct communication between the branchiæ and the peri-intestinal cavity; and this is afforded, according to Van Beneden, by the respiratory tentacles, see p. 1202.

Seen under the microscope, the contractile tissue of the heart affords no trace of muscular fibre. The contractility remains some time after the removal of this organ from the body; and that without being irritated.

Nervous system. — A single ganglion, oval, soft, consisting of a saclike neurilemma, enclosing nerve-cells or neurine, placed in the substance of the mantle, and between its two tubular orifices, gives off four branches, two of the branches forming a loop around either tube, and other lesser filaments distributed about

* Described by Eschricht (Royal Danish Trans. vol. ix. p. 12.), to whom we are indebted for much valuable information, both with respect to this genus and the Salpians.

* In the Physiological Series of the Hunterian Museum there is a highly illustrative dissection of *C. tuberculata* (No. 898. B.), prepared by Prof. Owen, that beautifully exhibits the heart and its pericardium, the branchial vessels, partially injected, and other organs.

† Recherches Zoologiques faites pendant un Voyage en Sicile. Comptes Rendus, 23 Nov. 1844.

the mantle. Besides these, Meckel* found in the *Ascidia gelatinosa* one larger and two smaller ganglia between the stomach and the branchial sac. Cuvier considered the large ganglion to be the analogue of the "inferior" ganglion of Molluscs, found in the Bivalves between the branchiæ and towards the origin of the tube that admits the water; and observed that he had not seen any nerves terminating at a brain, nor the brain itself, which must be situated by the mouth at the base of the branchiæ.

The great nerve-ganglion in *Chelyosoma*, $\frac{3}{4}'''$ long and $\frac{1}{4}'''$ broad, cylindrical, and yellow-coloured, lies near the middle of the inferior surface of the plated test, and a little to the left (*fig.* 777. *f*). From its anterior angle it sends four branches, two of which form a half-circle around the star-shaped muscular apparatus of the branchial orifice, the other two losing themselves in the muscles bordering the nearest plates. From the posterior angle arise eight nerves, four going to the anal orifice, and four to the lateral muscles of the plates (*fig.* 777. *d*, *g*).

Special senses. — In the last-named genus there are two remarkable bodies found in connection with the nerve-ganglion, which Professor Eschricht, to whom we are indebted for a careful anatomical description of *Chelyosoma*, considers probably to appertain to the function of *hearing* (*fig.* 777. *g*, *h*). One of these bodies has the appearance of a minute bladder, filled with a whitish substance. It measures $1'''$ long, and $\frac{1}{3}'''$ broad, and lies to the left of, and quite close to, the ganglion, being at its posterior extremity strongly adherent to it, or to the base of one of the nerves proceeding from it, by means of a stalk-like attachment. Through its diaphanous walls a row of arched transverse striæ are discernible, which are either folds of the parietes, or a partition. The other body is pear-shaped, about $\frac{3}{4}'''$ long, lying anterior to the ganglion and the little bladder-like body, and, like them, between the serous membrane and the respiratory sac; its stem is placed between these two bodies, and its head advances up to the hindmost muscle of the branchial orifice. It seems to be of tolerably firm consistence, but it is not at all bony or horny. Its thick, anterior portion is barely $\frac{1}{4}'''$ broad, and has anteriorly a deep hole, which seems to lead into a large cavity; the border on all sides of this pit is prominent, gently declining to a blackish little body within.

The *Ascidiæ* have frequently around the extremity of each process of the mantle, *i.e.* the branchial and anal tubes, a row of coloured points or *ocelli*, similar to the imperfect organs of sight present in the majority of the bivalve Acephalans, where they are arranged along the margin of the mantle, or dotting the edges of the siphonal orifices. The number of these oculiform points correspond with the number of processes or folds that the margins of the tubes respectively bear; about eight in the branchial, and six in the anal tube. They are usually red, as in *A. vitrea*, *A. virginea*, *A. prunum*, and others; in *A. mentula* they are yellow, with a central red spot.

M. Milne-Edwards has observed similar eye-like points around the oral tubes of *Amaurouçium* and *Parascidia*, belonging to the botryllian group of Tunicates.

Some of the *Salpæ* also have ocular spots.

Besides these oculiform points in the adult animals, Van Beneden has observed in the larvæ of *Cynthia ampulla*, on the side of the gibbous or anterior portion representing the head, some black points that he regards as true eyes. Speaking of the development of the young Ascidian in the egg, Van Beneden describes the separation of the contents of the incubated ovum into an external layer, to form the skin and the tail of the young animal, and a second layer, of which subsequently the walls of the alimentary canal are formed; and, thirdly, an internal vitelline mass. "In the thickness of the external layer," says Van Beneden, "there appears towards the middle of the body, and rather inferiorly, a cell filled with black pigment, which must be regarded as the organ of vision. It persists during the whole term of the animal's locomotive existence, and disappears after it becomes fixed. These organs," he adds, "which we may well call eyes, although so simple, are constant; sometimes two are discernible on one side."

M. Milne-Edwards has also seen in the larvæ of the compound Ascidians one or two blackish points, but towards the posterior extremity of the body; he merely notices them, without assigning for them any function. "We consider ourselves," says Van Beneden, "sufficiently authorised, by all that we have seen in the embryos of the free inferior animals, to elevate these pigment-cells to the dignity of an organ of special sense. To say that the presence of an eye implies that of an optic nerve and of a brain does not appear to us to be more just than to say that there are muscles when there is movement. We have the example of the *Hydræ*, that, without muscles, without nerves, without brain, and without a special organ of feeling, are sensible to light, and avoid or approach at will bodies whereby they are affected. And if the *Hydra*, without special apparatus, is sensible to light, we do not see why a cell of pigment may not be the first rudiment of the organ of sight. The appearance of the eye and the ear, in the animal series, takes place in similarly simple rudimentary forms."*

Generation. — The *Ascidiadæ* are all hermaphrodites. Between the fold of the intestine, and close to the liver, when the latter exists, there is observed a whitish glandular organ; this is the ovary. An undulatory duct passes from it, which, following the rectum, opens near its extremity into the cloaca. Opposite to the opening of the oviduct, Carus noticed the orifice of another glandular organ, which he thought to be either a male organ, or serving

* Schalk, De Ascidiarum Structurâ, Halle, 1814.

* Van Beneden, Mém. Brux. Acad. vol. xx. p. 40.

to furnish the gelatinous covering of the ova.

The ova of *Ascidiæ*, instead of passing from the ovary to the branchiæ, there to be developed as in a uterus, are emitted externally, by the oviduct conveying them into the cloacal cavity, whence they are carried outwardly by the current of water through the external anal aperture, or through the communicating lateral opening into the branchial sac, and thence through the branchial aperture. Cuvier says that he found some minute egg-like bodies between the branchial sac and the mantle; a position very analogous to that held by the ova of the bivalve Molluscs; and he thought it probable that ova so placed were fecundated by seminal fluid emitted by the same duct that leads from the ovary. These granules, however, M. Savigny apparently regards as little glands.

The generative organs are sometimes single and sometimes double; in the latter case, the two halves, right and left, are completely separate, as in other Acephalans, and emit their products separately into the cloaca, which serves as a kind of incubational or marsupial pouch.

The ovary is single in *Phallusia*, *Pandocia*, and *Dendrodoa ;* it is usually double in *Boltenia*, &c. In *Cynthia* the ovary is either single or multiple, sometimes very large, forming long groups of clustered globules, each globule being crowded with ova.

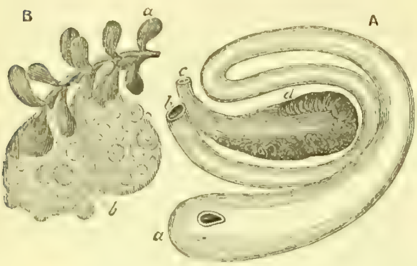
The single ovary is sometimes enclosed within the intestinal loop, without adhering to it, and sometimes, as in *C. papillata*, &c., it lies against, and is adherent to, the rectum. In *C. papillata* the ovary is bent on itself and terminates by an oviduct at each end. In *C. canopus* there are 2—4 or more ovaries ; those on the right side are placed against the rectum, and all terminate, as usual, by oviducts. In *C. microcosmus* there are two ovaries on the left side. They are composed of separate gelatinous lobes, having the appearance of a bunch of grapes. In *C. mytiligera* the ovary has the form of a membranous pouch, which furnishes points of attachment to the exterior of the branchial sac, and is fixed to the mantle and to the inner part of the intestinal loop. Its duct is very thin, and follows the usual course by the side of the rectum. In *C. polycarpa* and *C. pomaria*, Savigny describes certain numerous hemispherical or conical bodies adhering to the mantle, almost fifty in number, and disposed in rows, somewhat corresponding to the six branchial folds, as being possibly the ovaries of these species. These bodies are without ducts ; they are formed of a mass of granules resembling the eggs of some other Ascidians ; they are much compressed, and resemble a compound berry held in a 5-fid cup; they have apparently no communication with each other or externally, and are accompanied at their base with gelatinous, transparent, subpedunculated vesicles, apparently empty. In *C. papillata*, which has other generative organs, there are many rows of isolated, gelatinous, semitransparent, wrinkled vesicles, corresponding to the arrangement of the branchial folds, attached to the mantle, and receiving bloodvessels from it. The lobes of the ovary in *C. microcosmus*, after the emission of the eggs, wither into wrinkled vesicles closely resembling these sessile vesicles in *C. papillata*. Certain soft bodies observed in *C. microcosmus*, and somewhat similar to the above, Cuvier regarded as fat, serving as stores of nutritive matter ; but with this Savigny cannot agree. Savigny also points out the occurrence of various irregular, but somewhat similar fungous or fleshy excrescences on the mantle (*fig.* 39. *i*, *l*, Vol. I. p. 112.), ovaries, and intestines, sometimes even quite investing the latter; but these are quite distinct from the ovary-like bodies above described.

In *Boltenia reniformis* the ovaries are double, unequal in size, elongate, formed of coarse subcubical lobes, situated one on each side of the body, and directed towards the anal orifice; the right or smaller ovary, straight, claviform, fitting closely into the ascending loop formed by the stomach and intestine. The left ovary, larger and less lobulated, is on the opposite side, between the mantle and the branchial sac; it is undulating, and extends downwards behind the branchial vein. The tissue of these ovaries is a yellowish membrane of distinctly cellular structure, containing groups of large opaque ova and smaller clusters of exceedingly minute diaphanous granules. The ovaries of *Cystingia* are two free racemes composed of globular bodies, as in *Cynthiæ*, arranged on the two sides of the body with the branchial sac and stomach between them. In *Dendrodoa* (*fig.* 778. *k*) the ovary is single and branched, consisting of a trifurcate, cylindrical stem, bearing at its base on one side a forked branch, and on the other a simple one, all of the same thickness ; it is situated on the left side of the body between the mantle and the branchial sac. In *Chelyosoma*, Professor Eschricht describes as an ovary two darkish bodies, filled with vascular ramifications ; placed, one between the liver and the rectum, and the other around the fold of the intestine. Another somewhat similar organ, traversed by ramifying vessels, and placed at the anterior extremity of the body, is apparently the testicle. Connected with this organ, a distinct sigmoid duct runs to the right posterior angle of the body, from whence a filamentous tube passes along to the left posterior corner.* In *Cynthia ampulla* the generative organs are situated in the intestinal fold, and appear at first sight to form a single organ; but by the aid of the microscope two distinct organs, male and female, are easily recognised (*fig.* 779. A). The testicle forms a sort of framework around the ovary ; it is of a milky white colour, and is composed of an infinite number of short, twisted cœca, visible to the naked eye, and somewhat analogous to the seminiferous canals composing the testicles of higher animals. Three or four mammillary processes rise from the anterior

* Royal Danish Transact. vol. ix. p. 13.

surface of this organ: they are hollow in the centre, and emit a milky fluid, which is shed

Fig. 779.



A, *generative organs of Cynthia ampulla, situated in the fold of the intestine.* (*After Van Beneden.*)

a, stomach and its aperture (destitute of œsophagus); *b*, rectum and anus; *c*, ovary, with its outlet into the cloaca; *d*, testicle, enveloping the edges of the ovary.

B, *magnified portion of the reproductive organs of Ascidia grossularia.* (*After Van Beneden.*)

a, testicle; *b*, ovary and ova.

into the cloaca, and contains, or rather is almost composed of, spermatozoa, with disciform heads and filamentous tails. The ovary is blackish, and is situated in the midst of the testicle. Its situation corresponds to that of the ovary of the *Limaces* among the Gasteropods, which is surrounded by the liver. It is easily distinguished from the testicle by its colour and by the appearance of its contained eggs. The oviduct opens into the cloaca by the side of the anus. In *Ascidia grossularia* the eggs, seen through the walls of the ovary, are of a fine red colour, and are contained in separate sacs, the ovary appearing like a bunch of grapes (*fig.* 779. B). Van Beneden has distinctly seen in all of these ova the two germinal vesicles. The vitellus is at first white, but during development it becomes of a deep red. By the side of the ovary is another series of sacs without ova, and some free cells containing a great number of other more minute cells moving about in their interior, and which when shed swarm about like spermatozoa. These appear to constitute the male organ, and its disposition accords with that of the *Amaroucium argus*, and with that of the *Bryozoa* (Van Beneden).

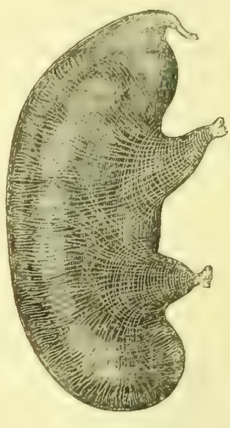
There remains much to be elucidated with regard to the generative functions of the Ascidians. The male and female organs are always associated together, and are apparently each provided with efferent ducts. It appears, however, doubtful whether or not occasionally the ova and the spermatozoa may not be brought into contact either in the organs themselves or in the ducts, as well as in the cloaca. We may notice that the disposition of the sexual organs in the *Bryozoa*, to which in so many respects the *Tunicata* bear reference, appears to be, from Van Beneden's observations, as follows. A male and a female organ are separately developed in the peri-intestinal cavity. Each is formed of cells, and in these cells are formed others, which become either vitellus or spermatozoa. When the latter cells are matured, the walls of the exterior or mother-cells are burst, and their contents are shed into the fluid filling the cavity around the intestine. It is here the male and female elements come into contact, and the ova are subsequently discharged by an orifice at the side of the anus.

In some compound Ascidians the peduncle-like post-abdomen forms a receptacle for the ova; and so does the pedicle of *Clavellina*, as in Cirrhipeds; but the pedicle of *Boltenia* and similar forms does not appear to be used for that purpose.

Muscular system. — The *Ascidiadæ* being fixed in their adult state, have no muscles of general locomotion; but they have numerous muscular bands by which they can effect certain movements of contraction and extension. The muscles do not consist, as in *Bryozoa*, of isolated fibres folding themselves irregularly during contraction; but each muscle is composed of many fibres united. They make their appearance in the young individuals contemporaneously with the appearance of the respiratory sac. The muscular fibre of *Tunicata*, like that of the whole of the *Acephala*, is of the organic or unstriped type.

In the *Ascidiadæ*, as in other Tunicates, the muscular tissue is chiefly developed in the mantle; the muscles of the heart and intesinal canal (if present) have not been observed. The muscles of the mantle are very thin and narrow bands, generally at considerable distances from one another, surrounding all the body of the animal from the anterior to the posterior extremity, and uniting in part with one another on the median line of the dorsal walls (*fig.* 780.),

Fig. 780.



Muscular sac or mantle of Boltenia reniformis. (*Original.*)

In *Ascidiæ* the mantle is more muscular on the anterior and largest part, and more membranous posteriorly. Externally there is a layer of longitudinal muscular bands, and internally of transverse bands. In some

(*A. intestinalis*, &c.) the exterior layer is much the thickest, and is composed of about twelve distinct fascicles, the fibres of which are somewhat separated from one another, insensibly disappearing on the anterior and superior borders. In others (*Cynthia microcosmus*, &c.), this external layer is very slight, and formed of distinct fibres, whilst the internal fibres are stronger, transversely oblique, and interlacing. Circular bands of muscles generally surround the tube of each orifice, and are rather stronger towards its base. The fibres forming these collars of the two tubes occasionally interlace with each other at the interval between the tubes, in a figure-of-eight pattern. Sometimes these muscular collars or sphincters are very indistinct, and not so apparent as another set of fascicles, which run in a diagonally transverse direction across the sac, and pass up the sides of the tubes, converging at the orifices. The latter bands diverge from the two orifices in two sets, which in part cross each other obliquely, and form an open network.

In *Chelyosoma* (*fig.* 777. *a*, *b*) each of the six triangular valvules that surround either orifice is furnished with a fan-shaped set of muscular fibres, adhering at one end to the inner surface of the test, and at the other extremity to a small papillary process on the valvule. Besides this set of muscles, and within them, is another set which passes laterally from one papilla to another, forming a sphincter, the base of which is hexagonal. There are other strong subcutaneous muscular fibres passing from the edge of the upper part of the tunic to that of the lower, and also from the edge of each of the coriaceous plates forming the upper surface (*c*, *c*).

By the action of these muscles, the body or inner sac of the animal is transversely contracted and somewhat lengthened; the tubular processes also of the mantle are closed, and more or less retracted. When the animal is alarmed, the contraction takes place rapidly, causing the water contained in the respiratory and cloacal cavities to be ejected by one or other of the orifices to the height of even three feet.

There is considerable analogy between the muscular system of the *Ascidiæ* and that of the *Bryozoa*. In the latter there are retractor muscles of the sheath and the intestinal tube; and in the interior of the cells there exist also transverse oblique cords, traversing the peri-intestinal cavity, and attached to one or the other surface of the skin. These transverse muscles contribute to open the tentacular circlet; and in the *Ascidiæ*, by their contraction, produce the jet that escapes from each of the two apertures.

Embryo-genesis of the Simple Ascidians.—In examining under the microscope a portion of the ovary of a recent *Ascidia*, eggs in all stages of development may often be observed. In describing the various conditions and modifications of the ova of this family in course of development, we shall borrow largely from the careful and extensive researches given to the world by Professor Van Beneden, to whom naturalists are so deeply indebted for much valuable information on the subject of the embryo-genesis of many of the *Polypifera** and other groups of animals. The earliest form of the ovum is a simple vesicle; it next appears as a vesicle with an inner vesicle, which is evidently "the vesicle of Purkinje;" and, thirdly, with a second, still smaller vesicle, "the vesicle of Wagner;" these latter vesicles, one within the other, being enveloped in the outer or vitelline membrane (*fig.* 781. A).

The space between the external membrane and Purkinje's vesicle is occupied by a substance, at first clear and probably fluid, but soon appearing granulated, constituting the vitellus. This yolk increases rapidly, soon occupying the whole ovum: at the periphery its granules or cells become organised (*fig.* 781. B), uniting among themselves, and forming a continuous sacciform membrane. The mode of growth of the vitellus is by new cells being formed in the interior of the large older cells, and subsequently producing others in their own interior. The growth of the whole ovum is evidently carried on by this process.

The whole surface of the vitellus soon afterwards becomes embossed, presenting a mulberry-like appearance (*fig.* 781. C). The germinal vesicles disappear. At the centre of each little mammilla of the surface a transparent vesicle becomes distinctly visible, and the whole appear like so many ova each with the vesicle of Purkinje. These mammillæ increase, and their peripheral substance rapidly becomes granulated, in a similar manner to the change that took place in the whole vitellus. The mammillated appearance is now soon lost from the growth of the granules, and the surface becomes uniform, the mammillæ of the periphery uniting into a membrane, which constitutes the blastoderm. According to Milne-Edwards, the blastoderm in the *Botryllidæ* is formed at a determinate point only; but in *Cynthia ampulla* (the species in which Van Beneden watched the modifications of the ovum) the latter observer feels assured that it is formed simultaneously all over the yolk, as in all the inferior animals. At this period a number of vesicles become somewhat regularly arranged over the exterior of the ovum, which by their union with one another form a new enveloping membrane. Beneath this membrane a space, occupied by fluid, soon becomes apparent. All over the exterior of this new membrane are distributed white, transparent vesicles, having much the appearance of oil globules. This envelope soon becomes more and more extended by the increase of the contained albuminous fluid, and a second membrane appears beneath it, on the surface of which also oil-like globules become apparent, as on the external membrane (*fig.* 781. D). The ovum is now composed of an external membrane, of a white

* See POLYPIFERA; also Papers by Prof. Van Beneden on Campanularia, Tubularia, and Bryozoa, Mém. Brux. Acad. tom. xvii. xviii. and xix.

fluid layer, another thin transparent membrane, an organised layer forming the periphery of the vitellus, and lastly of the soft yolk in the centre, the vitelline membrane and the blastoderm forming one with the vitelline mass.

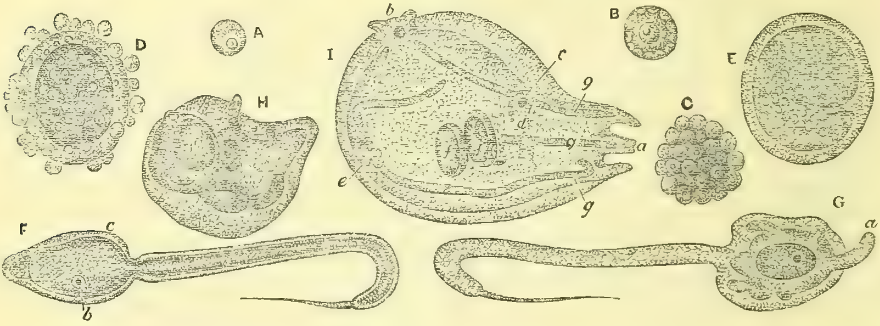
The external membrane and the albuminous layer beneath it appear to be formed externally to the ovum by the oviduct or the ovary; and as they envelop the ovum after its complete development, they may be considered only as accessory parts.

It being uncertain whether the ova in which these changes take place, have been subjected to fecundation whilst still in the ovary or oviduct, there arises the interesting question as to what extent of modification, even to the disappearance of Purkinje's vesicle, and the mulberry-like condition of the vitellus, can take place before the ovum has received the stimulus of the seminal element.

During the changes of the ovum in this first period of its development, the colour of the egg is occasionally subject to certain modifications. In *Ascidia grossularia*, the ova become of a bright red colour, and in some species no change of colour takes place. In *Amaroucium*, a compound Ascidian, the ova change from a pale to a deep yellow.

The second period of development is marked by the prolongation of one side of the yolk to form the caudal appendage. The ovum has now a chorion, albumen, and yolk, the two latter being separated by a fine membrane. The vitelline or embryonic mass becomes contracted about its middle, and is somewhat bean-shaped. From this time there are observable two extremities, one lengthening itself, as the other becomes more and more globular; and respectively representing the caudal appendage and the body (*fig.* 781. E).

Fig. 781.



Development of Cynthia ampulla. (*After Van Beneden.*)

A, ovum, with the vesicles of Purkinje and Wagner. B, the same further advanced, with surrounding vitelline globules. C, the central vesicles have disappeared, owing to the development of the vitellus; the ovum presents the appearance of an agglomeration of ova, or the mulberry-like aspect. D, further developed ovum, with double external membrane and intervening transparent liquid. E, the yolk elongated, partially divided in the middle; the larger portion becoming the trunk, and the narrow portion the tail, of the larva. F, the embryo at the full term of incubation: *a*, anterior process; *b*, eye; *c*, integument. G, the same, further advanced; the caudal portion entirely absorbed, leaving the tegumentary elongation empty; *a*, anterior process. H, the same, further advanced; superficial appendages still present; internal organs more distinct. I, embryo nearly perfect; *a*, branchial orifice with tentacles; *b*, anal orifice; *c*, eye; *d*, œsophageal collar; *e*, (?); *f f*, ciliated circles, rudiments of respiratory organs; *g*, *g*, *g*, muscular bands.

The former of these becomes more and more elongated, following the outline of, and folding itself around, the body, which is included in the ovum, as in many reptiles.

In *Amaroucium*, according to Milne-Edwards' observations, the tail is formed by the marginal portion of the yolk being condensed, at the same time that the body is flattened, and then separated from it throughout its length. Van Beneden, however, remarks, that in the simple Ascidians, as we have stated above, the tail is rather an elongation of one part of the yolk, and that, like the exterior organs of all other animals, it is formed by extension and not by division or separation.

The body part of the embryo has an internal cavity, and is formed of the yolk; it is surrounded by the membrane, which becomes the skin of the body and tail. The caudal appendage is hollow, and communicates with the central cavity; it does not in *Ascidiæ* present the spiral or zigzag cavity observed in the *Botryllidæ*.

There is soon formed within the embryo another layer distinct from the exterior, and which is destined to become the parietes of the intestinal tube. There exist then two layers, internal and external, from which all the organs are derived. In the thickness of the external layer, near the middle of the body, and rather superiorly, occurs a black pigment-cell, which Van Beneden regards as a rudimentary eye. In *Amaroucium*, Milne-Edwards has observed one or two blackish oculiform points towards the posterior extremity of the body.

The chorion is now ruptured, and the larval embryo appears with a pellucid membrane covering its body and tail (*fig.* 781. F). This membrane has been already mentioned as investing the ovum at a late stage of the first period of its development, immediately after the vitellus lost its mulberry aspect, and when the albumen was formed. It closely envelopes the caudal appendage, and terminates beyond it by a tapering prolongation: subsequently it becomes the test of the animal. The larva, resembling in appearance a frog-tadpole, still remains a while in the cloacal pouch, but is soon carried out by the current leaving the animal: it is very active, wriggling about for hours. After a brisk locomotive existence for about twelve hours, the embryo fixes itself to a foreign body. The tail then begins to disappear, being slowly absorbed; its pellucid membrane remains entire for a little time, but is ultimately detached from the body. At the same time other appendages spring from the body, the principal one of which arises from the anterior extremity, elongates itself more and more, attains a trumpet-like shape, and may be considered as the future mouth (*fig.* 781. G). In *Amaroucium*, Milne-Edwards observed generally five appendages arising from the anterior extremity of the body, two of which soon disappear, and the three others, which are persistent for a while, terminate in button-shaped, dilated suckers, touching the parietes of the external integument. In *Cynthia ampulla* other processes or appendages occur all over the body; these are somewhat similar to the anterior appendage, but are never constant, either in direction or number; one specimen had seven appendages on one side. Sometimes the numerous appendages resemble tentacles, giving the embryos the appearance of young *Tubulariæ*.

These processes are hollow, communicating with the central cavity. None of them appear to open externally, or to be at all like suckers; and a considerable space frequently exists between them and the enveloping membrane.

The young animals are attached to solid bodies by this external tunic, on a different side to that at which the orifices make their appearance. "If," says Van Beneden, "the appendages served as suckers for attachment, the animals would have the mouth on the side by which they are attached."

It is at this stage of growth that the walls of the internal cavity are distinctly seen through the external membranes. The contents of the digestive tube are seen to consist of a rather opaque mass, distinct from the surrounding clear space.

As soon as the animal is fixed, the transparent membrane that has remained floating since the absorption of the caudal appendage, is completely detached, and the integument and the test begin to be formed.

In the third period of development the embryo takes on the ascidian character. The development of the internal organs progresses, and the external orifices become apparent (*fig.* 781. H). At the commencement of this period, the form of the young Ascidian varies considerably. The numerous appendages disappear, just as the caudal appendage was lost. The embryo becomes rounded and larger, and its substance is distinctly seen to be disposed in three layers. Up to the present time the vitelline cavity has had no external communication, but the mucous cavity is now extended on one side, to form the mouth. The mucous layer is elongated also on the opposite side, but instead of reaching the exterior, it is folded back on itself, forming the intestinal loop. The yolk soon opens a passage on each side, constituting the oral or branchial, and the ventral or anal, orifices. The intestinal tube becomes completed by its separation into the respiratory, the digestive, and the cloacal cavities. Around each external orifice certain nipple-like, palpiform bodies appear, which soon lengthen, but before long they are hidden by the integument (*fig.* 781. I). The eye-like pigmentary spot still continues for some little time, and is situated in the middle of a band (the œsophageal collar) that seems to embrace the respiratory cavity. At the base of the intestinal cavity, the opaque concretionary body appears, to which the heart is subsequently attached, and which Van Beneden considers to be analogous to the internal shell of the *Limaces*. This is furnished with vibratile cilia, which occasion circulatory currents, until the heart makes its appearance in the form of a thin, gently pulsating, membranous body. Contemporaneously with these cilia, others appear in the interior of the branchial sac, in the form of a ciliated circlet, to which a second and afterwards others are added, forming altogether the peculiar branchial tissue. These cilia give rise to currents in the digestive and subcutaneous cavities. The young Ascidian can now carry on the functions of respiration and digestion.

At the surface of the skin, and around the anal and branchial cavities there are apparent longitudinal striæ, which are evidently the rudimentary muscular bands. The sphincters, also, at the two extremities of the intestinal tube, are brought into action. Some slight further modifications only are now required to perfect the development of the little *Ascidia*.

Anatomy of Clavellinidæ.—*Clavellina.*—At the superior extremity is the buccal orifice, which is circular, looking directly upwards (*fig.* 768. *c*), and furnished with a very thin, prominent, cylindrical margin; to the interior of which is attached a ring or circlet of simple tentacular filaments, about thirty in number, of which about ten are long enough to reach to the centre of the cavity of the tube, whilst the others are very short, and situated between the first. Near this first orifice, and toward the superior part of the dorsal aspect of the thorax, is the second or anal orifice, which is also circular, with an entire rim. The external tunic or tegumentary membrane (test) of the body is thin, but subcartilaginous. It adheres feebly to the other parts, except around the two orifices. At its base, or inferior extremity, there are a variable number of radiciform prolongations, which serve to fix the animal, and some of which often bear at intervals little pyriform tubercles, which become developed into new individuals.

The test is so transparent and colourless, that the interior structure of the animal may be easily studied without having recourse to dissection. There is observable, however, certain yellowish lines traversing the transparent test, which have a granular appearance, and correspond, according to M. Milne-Edwards, to the lines of junction of certain parts of the interior. Two of these bands descend vertically, very near one another, throughout the medial line of the ventral surface of the thorax, and are separated by a linear, colourless, semi-opaque space. A third line rises on the right and left of the test, at the superior part of the thorax, and is directed horizontally backwards, describing a circle around the base of the oral orifice. A fourth line, also annular, encircles the inferior extremity of the thorax. A fifth surrounds the anal orifice, and is prolonged upwards and forwards, almost to the posterior margin of the oral orifice. There is generally a sixth line, much paler than the others, and more deeply situated, at some distance from the dorsal surface of the thorax, descending vertically from the superior to the inferior ring.

Towards the middle of the abdominal portion of the body the *stomach* appears, as a small, orange-yellow, oval mass, bearing four yellow vertical lines, like those of the thorax. Lastly, close to the stomach, is another orange-coloured spot, formed by a coloured portion of the *intestine*, and, still lower, the whitish gland-like mass, comprising the *generative* organs (*fig.* 768. *p*).

The *mantle* is suspended within the first tunic; it is membranous and extremely delicate. Superiorly it is attached around the two orifices, and inferiorly it terminates in a *cul-de-sac*. It often presents inferiorly some tubular prolongations, sometimes simple, sometimes ramified; which descend towards the base of the animal, and sometimes project into the interior of the root-like processes of the external tunic. Its surface is traversed with divers muscular fibres, some of which are circular, and constitute the sphincters around the mouth and anus; whilst others, to the number of nine or ten pairs, arise from a kind of tendinous collar surrounding the mouth, and descend vertically to the inferior extremity of the abdomen. These last muscles serve to shorten or bend the body, and it would appear that it is by the elasticity of the external tunic that they are lengthened again, after having been so contracted, for there do not appear to be any traces of transverse muscular fibres proper to act as antagonists to the vertical fibres.

In all the thoracic portion of the body a third tunic is present. This, like the preceding, is membranous, and is suspended in a kind of sac formed by the latter; it adheres to it by the rim of the anal orifice and along the collar around the base of the mouth. Inferiorly this membranous pouch is united in its extent to the two orifices of the digestive canal, where for the most part it is continuous with the wall of that tube. Its cavity constitutes the *thoracic chamber*. It encloses the branchial organs, and presents on the dorsal side a free space, which forms a kind of *cloaca*, ending at the anal orifice of the external tunic. Along the medio-ventral line a vertical groove is observable, and at the point where it adheres to the second tunic, between the mouth and the anus, we can perceive a minute tubercle, which is the nervous ganglion. This thoracic chamber exactly resembles the great cavity of the Salpians, and would scarcely differ at all, if the *cloaca* were shorter, and the anal orifice more distant from the mouth, and directed backwards.

The *branchiæ* (*fig.* 768. *e*) exist as a large membranous band, arising from the dorsal surface of the thoracic cavity, below the gangliform tubercle, and by its opposite extremity fixed to the space situated between the œsophageal orifice and the termination of the intestine, thus separating the cloacal from the great pharyngeal or respiratory cavity; only, in place of presenting on each side simple striæ furnished with vibratile cilia, as in the Salpians, this kind of vertical body bears right and left a series of filiform appendages, directed horizontally towards the ventral side of the respiratory cavity, where they are fixed on each side of the middle sulcus, and, during their passage across, are united together by a number of other slender vertical filaments. From this disposition of the parts there results a kind of trellis-work, which fills up all the pharyngeal portion of the branchial chamber, permitting no communication between the latter and the cloaca, except through the meshes of its network, which are bordered all around with vibratile cilia. This complicated branchial apparatus adheres also to the thoracic tunic by its two extremities. The dorsal column, which thus forms the base of the branchial organ, and which represents the simple branchia of the Salpians, is considerably prominent in the interior of the respiratory cavity, and exhibits along its ventral margin a series of ten membranous languets, which are usually straight, and are apparently susceptible of a kind of erection. The interior of this membranous band is occupied by a large vascular cavity, which M. Milne Edwards terms the *branchial* or *dorsal sinus*. The transverse little fillets which spring therefrom are in number about twelve pairs, and the vertical filaments that unite the latter are nearly of the same size: these are about thirty in a rank, and there are thirteen ranks, viz. eleven situated between the two transverse fillets, and two which stretch from the first and second fillets to the wall of the thoracic chamber, and are fixed along the two yellow lines, placed as rings at the two extremities of that chamber. Some membranous processes appear also to stretch from different points of the surface of the branchial net-work to the walls of the cavity in which the latter is suspended; but these are few, and do not hinder the eggs, deposited in the cloaca, from insinuating themselves frequently into that portion of the cavity situated on each side of the respiratory sac. The spaces circumscribed by the narrow elongated meshes, supported by the vertical filaments, and bordered with vibratile cilia, are not occupied by a membrane, but form openings, somewhat like a button-hole, called *branchial stigmata*. These chinks or spiracles, through which the water passes from the branchial sac in the thoracic chamber to escape outwards by the anal orifice, are consequently disposed in the same manner as the vertical filaments that circumscribe them, that is, parallel to each other and in transverse ranks, thirteen in number. Lastly, each of these vertical filaments is perforated by a canal, opening by its two extremities in other similar but larger canals, that occupy the interior of the transverse fillets. The latter vessels in their turn empty themselves by one of their extremities into the great dorsal or branchial sinus, and by the opposite extremity into the vertical fold of the ventral wall of the thoracic chambers, which is circumscribed by two parallel, vertical, yellow lines, and which places the respiratory organs in relation with the great *thoracic sinus*, lying between this chamber and the ventral portion of the internal tunic of the body. These two sinuses communicate also one with another by the vessels that surround the branchial orifice, and from which spring other vessels that descend towards the abdomen.

The pharyngeal portion of the thoracic chamber, tapestried with the branchial network, opens externally at its upper extremity, by the branchial aperture, which occupies nearly the whole of its diameter, and is furnished with a kind of radiating net-work of tentacular filaments. This cavity is cylindrical, and at its inferior extremity has a large transverse slit, the opening of the œsophagus, opposite to the external oral aperture. The *œsophagus* is large, and descends vertically into the abdomen terminating in the *stomach* (*fig.* 768. *l*), which is ovoid and swollen. The *intestine* (*m*) springs from the inferior extremity of the stomach, and at first running vertically downwards, and then bending forwards and upwards, so as to form a loop, it ascends towards the thorax by the side of the stomach and œsophagus, slightly covering them on the right side. Arrived at the superior part of the abdomen, it is again bent, passes by the side of the œsophagus, ascends rather behind the branchial sac, and terminates at the inferior part of the cloaca (*n*), at about the level of the antepenultimate row of the branchial stigmata. Throughout its length the intestine preserves nearly an equal calibre, but varies in its appearance, and is divisible into three portions.

The first part, the *duodenum*, succeeding to the stomach and forming the intestinal loop, is colourless and transparent. The next portion, placed on a level with the stomach, but on the ventral side of the body, is on the contrary of a dull-yellow colour, and the tissue of its walls has a glandular appearance. This M. Milne-Edwards considers to be the hepatic portion of the alimentary canal, and comparable to the organ known in insects as the *chylific ventricle*. Lastly, in its third portion, the intestine again becomes membranous and colourless: here the fæcal matter is collected into brownish pellets, and from its functions and position this portion of the tube is termed the great intestine, or *rectum*.

To the right of the intestinal loop is placed a glandular mass, the chief part of which is formed by the *ovary*, recognised by its vesicles, and by the eggs of different degrees of development contained in it. Below the ovary is the *testicle*, a mass of whitish and ramifying filaments, spread out in some degree on the intestine. From this glandular mass arises a milk-white filiform canal, which ascends between the stomach and the intestine, passes on the left side of the œsophagus, and opens into the cloaca, near the orifice of the rectum. This canal contains a silvery white fluid, crowded with spermatozoa, and must be considered as a *vas deferens*. There being no other visible duct leading from the ovary, this canal perhaps serves also as an *oviduct*. The *eggs* are minute, circular, and of a greenish yellow colour.

The *heart* is situated at the inferior part of the abdomen, lying against the intestine and the ovary, to the right and in front of the former, at the posterior part of the cavity of the mantle, between the tunic and the intestine, and much resembles that of *Ascidia intestinalis*. It is enclosed in a membranous sac or pericardium, and is cylindrical in form; its superior extremity is on a level with the centre of the stomach, and its lower extremity, turned up a little behind, passes sometimes a little beyond the intestinal loop.

The *Perophora*, first described by M. Lister in Phil. Transact. 1834, p. 378., as a "small *Ascidia*," is parasitic on Confervæ, &c., and appears to the eye like minute lumps of pellucid jelly, with a spot of orange and grey. The group consists of several individuals, each having its own circulatory, respiratory, and digestive systems, but fixed on a pedicle that branches from a common creeping stem, and all are connected by a circulation that extends throughout. They are very transparent, and their interior is easily seen. The two orifices are very short tubes; the branchial is at the summit, and the anal is a little lower down. The longest diameter from the peduncle to the space between the openings is about ·085 inch (see *fig.* 306. A and B, p. 623. Vol. I. CILICI). The test is subcartilaginous and tough, more pliable near the orifices. It is lined internally with the soft mantle, in which a ramifying circulation is very distinct. A great part of the interior is occupied by the branchial sac, which is subcylindrical, flattened at the sides, and has its axis vertical. It is united to the mantle above and behind; the juncture, beginning in front of the oral opening, extends backwards on each side of it, and then downwards in two lines; between these, along the middle of the back, is a vertical compound stripe. At the bottom, the branchial sac appears to be in contact with the mantle, but at its sides and front a vacant space is left between them, communicating with the anal orifice (see *fig.* 306. B, *f*, loc. cit.). The sac is more compressed towards its lower part; and here are placed, externally to it, the heart on the left, and the stomach and the other viscera on the right side, the anus opening upwards into the cloaca. On its sides and front the sac is perforated by four rows of narrow, vertical, irregularly oval holes or spiracles, about sixteen in each row, placed at less than the diameter of one of them apart from each other. Through these the water, which flows constantly in at the mouth when its orifice is open, is apparently conveyed to the vacant space between the sac and the mantle, and it then escapes by the anal orifice. The branchial tissue is extremely thin between the stigmata, but their edges are thickened, and are lined with closely set cilia, which by their motion cause the current of water. When these are in full activity, the effect upon the eye is that of delicately toothed, oval wheels, revolving continually in a direction ascending on the right and descending on the left of each oval, as viewed from without; but the cilia themselves are very much closer than the apparent teeth, and the illusion seems to be caused by a fanning motion made by them in regular and quick succession, producing the appearance of waves, and each wave answering to the apparent tooth. The spaces between the rows of spiracles are of much more substance than the intervals between the spiracles in a row; filamentous processes are stretched from them across the side cavities, attaching the branchial sac to the mantle: these spaces also support finger-like processes, about eight in a row, that project nearly at right angles into the central cavity.

The large short tubes of the branchial and anal orifices have each five or six obscure marginal indentations, and can be drawn in and closed at the will of the animal. Within and at the bottom of the branchial tube are numerous, simple, tentacular filaments of different lengths. The particles drawn into the branchial sac by the current of water are seldom stopped by these tentacles, but lodge somewhere on the branchial net-work. A lively animalcule will sometimes disengage himself by struggling, and dart about in the cavity until he lodges on some other part; or if a morsel is found unsuitable, it is ejected by the funnel's being closed, and the branchial sac suddenly contracted vertically. Mostly, however, whatever part the food lodges on, it travels from thence horizontally with a steady slow course towards the front of the cavity, where it reaches a downward stream of similar materials; and they proceed together, receiving accessions from both sides, and enter at last, at the bottom, the *œsophagus;* which is a small flattened tube, carrying them, without any effort of swallowing, towards the stomach: the œsophagus takes a sharp curve upwards and backwards before arriving there. "It is extraordinary," observes Mr. Lister, "that the particles pass along so near to the spiracles, with their cilia in full activity, without being at all affected by them." "I have, says he, "in some positions, seemed to catch a glimpse of a membrane suspended within, too transparent to be commonly seen. One may imagine the water to pass to the spiracles strained through the meshes of such a membrane, and the food to be carried along it by invisible villi; but this is mere conjecture."

The *stomach* runs backward horizontally. When seen from the side, its anterior portion has an inflated appearance, and, when from below, it seems to possess two lateral lobes. The *liver* has an ochreous tint, and envelopes the anterior portion of the stomach. The *intestine* on leaving the stomach rises, and then bends forward with a sigmoid flexure, and terminates in an ascending rectum and sphincter.

Transparent vessels ramify along a part of the intestine, and meet at a collection of globular bodies, from whence, in one individual, two flattish lobes were observed to extend backwards. These globular and lobate bodies probably constitute the *generative organs.* From the meeting of the above-mentioned vessels two branches run; one downwards and backwards, but under the stomach, the other forwards. From their direction Mr. Lister supposed them to communicate with a main stream of blood near the heart.

The *circulation* in these animals is very interesting, and easily discerned through their transparent tissues. The blood circulating in one individual of the group descends by the peduncle into the common root-like stem, and penetrates into the next member of the group, so that there exists in these Ascidians a common circulation, having as many centres and motive organs as there are animals growing on the same stem. The blood-globules are very numerous, and though not uniform in size or shape, are mostly between ·00025 and ·0002 inch in diameter, and approaching to globular. They are easily measured, as in the intervals between the stigmata they pass mostly but one at a time. The creeping tube, which unites the individuals of a group, contains two channels for two separate currents of blood, an upward and a downward one, that are flowing at the same time, and that send off each a branch to every peduncle. The blood then passes into the animal by one current, while another carries it back. One of these canals communicates, at the termination of the peduncle, with the heart, which is placed, as before mentioned, near the bottom of the branchial sac on the left side, and consists of a transparent ventricle or tube, running forward and a little downward, in a channel hollowed to contain it. Along the whole length of this tube, a part on one side of its axis seems fixed to the channel, the rest is free and contractile. Mr. Lister observed that when the blood entered the heart from the peduncle, contraction began at the middle of the ventricle, impelling onward the contents of the forepart; and the contraction of the back part followed in the same direction, so as for the whole to have the effect of one pulsation. The heart was then filled again by a flow from the peduncle. The intervals of the pulse were pretty regular in the same individual; but in different ones they varied from two seconds to one and a half second. Part of the blood thus impelled formed a main upward stream along the front of the branchial organ, branching off at each of the horizontal passages between the rows of spiracles, and traversing the space above them on a line with the junction of the branchial sac and the mantle on each side. All these streams again united, and formed a downward current behind. The horizontal vessels were connected also by the smaller vertical channels between the spiracles; the set of the current in the latter being upwards for the two lower rows, and downwards for the two upper rows.

Another large portion of the blood, on leaving the heart, immediately divided into many ramifications, that spread like a net-work over the stomach and intestines, and over the mantle. Of these, a part ran into the horizontal passages above the branchial sac, a part into the descending dorsal vessel. A large proportion, after leaving the intestines, took a short course, and collecting into one channel, flowed into the dorsal vessel near the bottom, and all, united, then entered the peduncle, and constituted the returning current that went to circulate in other animals of the group. After this circulation had gone on for a while, the pulsations became fainter for a few beats, and the flow slower, and suddenly, with but slight pause, the whole current was reversed, the heart gave the opposite impulse. The vessel in the peduncle that before poured in the blood, now carried it back, and the other channel the contrary, and every artery became a vein. These changes continued to succeed each other alternately. The average time of the currents being the same in both directions, but the period of each varying within a single observation as much as from thirty seconds to two minutes. Mr. Lister points out the analogy between this phenomenon and the very similar circulation that obtains in the stem of the *Sertularia*, described by him in the same volume of the Philosophical Transactions. This acute observer goes on to say, that sometimes, when the creeping tube, or the peduncle, has been injured, the circulation of an individual is in consequence insulated, but without appearing to impair any of its functions. In one animal which was severed from the peduncle, the pulsation ceased for a few seconds. It then began irregularly, and with considerable pauses, increasing in steadiness as it went on. At first the impulse given by the heart was towards the front; and the downward back stream, instead of flowing out at the wound, was poured into the hinder end of the ventricle; the cut end of the vessel leading from the heart being nearly opposed to the bleeding dorsal vessel cut through at the same place, and the two vessels, in their undisturbed state, lying across each other at this point. But when the current was reversed, part of the blood was driven for a time through the stump of the peduncle into the water; however, it soon staunched, and all the vital actions went on as before the separation, except that at the beginning of every pulsation there was a slight recoil.

In one case, where the circulation did not extend to another animal, one channel only was observed to be open in the peduncle, and in this a small current ran to and fro according to the direction of the impulse given by the heart. Some animals, which had probably been injured, but were still connected with other vigorous ones, seemed to be in course of absorption. One was observed in which the soft parts were so shrunk as to occupy a small part only of the tunic. The currents of its peduncle extended into this mass, but no heart or motion of branchiæ was visible. Upon looking at the same the next day, the tunic was empty, the soft matter and the circulation reaching only to the end of the peduncle. Mr. Lister also once noticed a flux and reflux of the blood in a creeping stem, where the current did not communicate with any animal. In the buds sprouting from the stem, and destined to become new animals, the two streams of the stem run through the germ before its organs are developed.

The *generation of the Clavellinidæ* takes place in two ways—by ova and by buds. The genesis of the larvæ of *Clavellina* from the ova is very similar to that of the larval *Ascidiæ*. The young of *Perophora* have not yet been observed. The method of the gemmiparous reproduction, according to the observations of Milne-Edwards, is as follows: Amongst the radiciform processes springing from the base of the test of *Clavellina*, and tending to preserve the animal in its position, are other filamentous prolongations which are hollow, and enclose a membranous tube, continuous with the internal tunic of the animal, and through which the circulation seen in the interior of the abdomen is also continued. This stolon-like body is closed at the free extremity; it is at first simple, but as it lengthens, it becomes ramified; and when its growth is further advanced, there are developed on the extremities of its branches, and even at different points along its length, tubercles, enclosing in their interior a minute organic mass connected with the interior tube. These tubercles rise vertically, and become elongate and claviform. The blood that circulates in the stem at first penetrates into the soft, pear-shaped, pedunculated mass occupying each of the tubercles; but after a while these little germ-masses lose their peduncle and their attachment to the internal tunic of the principal canal, and participate no more in the circulation of the mother-animal. By further development they soon put on the ascidian character. The branchial sac is perfectly distinct, although not yet communicating with the exterior; and the digestive tube bent loop-wise, below the thorax, is plainly discernible. Lastly, the oral orifice appears, and the general form of the young animal approaches more and more that of the adult. From this a new individual is then in like manner produced by stolon and bud, remaining attached to the mother by the former, and which at first has a circulation in common with the older animal, but soon enjoys an independent existence. The individuals either remain attached by the intermediate root-like prolongations, or become separate by the disunion of these slender filaments.

In one species of *Clavellina*, the bud-like bodies and young animals are produced not only on the root-like stolons, but also on the walls of the test itself (*fig.* 768. *u*, *u'*).

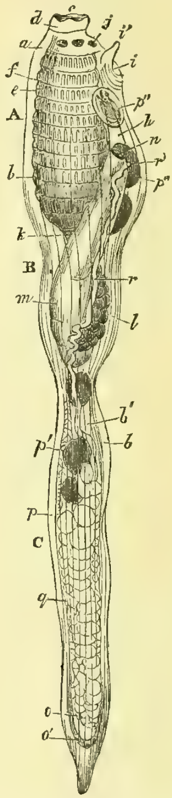
In *Perophora* the growth of the buds is confined to the extremity of the creeping, root-like tube, and the attachment of the individuals by the common root-stem is permanent through life, and not merely existent during the young state.

Anatomy of the Botryllidæ. — A description of the form and structure of the test of these compound Ascidians has been already given. The in- and out-lets of the aggregated individuals, as we have already seen, have either separate external openings, or the several vents of a "system" of animals unite to form one large common cloaca and external anal orifice.

All these external orifices are more or less irritable and contractile. When the little animals dilate their branchial orifice, a part of their body is raised so as to slightly emboss the general surface of the mass, and they protrude a membranous circlet or ring, the free border of which is cut into, generally six, regular lobes, but sometimes into eight. In *Polyclinum*, the mouth is very contractile, and is surrounded by six little digitiform processes. *Parascidia* has eight of these tentaculiform bodies. Frequently, after death, as in *Leptoclinum*, these orifices contract, and their borders sink in so as to be discerned with difficulty. In the interior of this orifice, and towards the base of the collar, a series of minute tentacular filaments can be perceived by the aid of a lens, which are directed, like the spokes of a wheel, towards the centre of the opening, or have a more or less curled appearance, in a similar manner to the tentacles occupying the same position in the simple Ascidians and in the *Clavellinidæ*. The tentacles vary from four to twelve or more, but nine or ten is their usual number; they differ materially in length, some being nearly rudimentary, whilst others, alternating with the first, are long enough to meet across the opening. In *Amaroucium Nordmanni* there are six long and six short tentacles within the branchial tube. In *Botryllus smaragdus*, in which the buccal orifice admits of considerable dilatation, a circlet of four longish filiform tentacles may be seen. The tentacles in *B. aureus* are more numerous than usual, but both in this species and in *B. violaceus* they are almost rudimentary. *Diazona* has fifteen or sixteen simple tentacles, and in *Sigillina* there are twelve.

Around the base of the denticulated rim of the branchial orifice in *Amaroucium argus* (*fig.* 782.) there are seen four minute pinkish spots, which are probably rudimentary organs of sight. Similar, but more numerous, pigment-spots are observed in *Leptoclinum Listeri*, *Parascidia*, and other genera.

Fig. 782.



Anatomy of Amaroucium argus. (*After Milne-Edwards.*) *An isolated individual considerably magnified.*

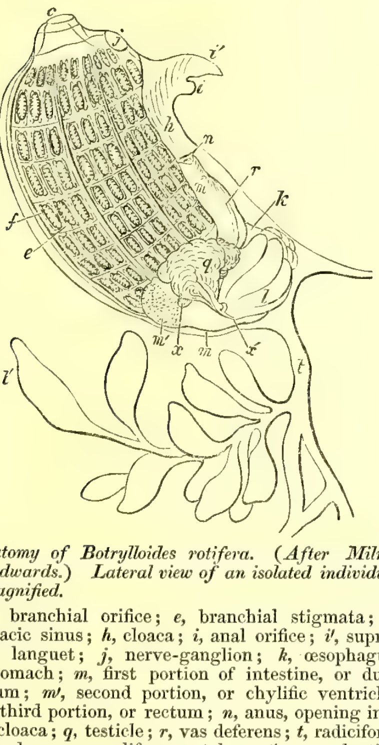
A, thorax; B, superior abdomen; C, post-abdomen; *a*, proper tunic of the individual; *b*, thoracic tunic; *b'*, longitudinal muscular fibres of the inner tunic; *c*, branchial orifice; *d*, branchial collar, below which are seen the oculiform points; *e*, branchial sac; *f*, thoracic sinus; *f'*, transverse vessels of the branchial sac; *h*, cloaca; *i*, anal orifice; *i'*, and appendage or languet; *j*, nerve-ganglion; *k*, œsophagus; *l*, stomach; *m*, intestine; *n*, anus, opening into the cloaca; *o*, heart; *o'*, pericardium; *p*, ovary; *p'*, *p''*, ova, passing towards the cloaca; *q*, testicle; *r*, *r'*, vas deferens, and its opening in the cloaca.

The separate anal orifices are frequently destitute of the crenulated or denticulated margin that surrounds the branchial tube. This condition has afforded a distinguishing character for some of the minor groups in Milne Edwards' classification of the *Botryllidæ*. In *Polyclinum*, *Amaroucium*, *Botryllus*, and other genera, the anus, instead of opening directly outwards, empties itself into a common cloacal cavity, that belongs to a number of individuals, and is in the form of a large canal hollowed out of the common tegumentary mass. This is frequently ramified interiorly, as in *Botrylloides*, and terminates at the opposite extremity by a simple excretory orifice, not occupying the centre of the "system," but placed nearly at one of the extremities, and communicating with the individuals situated at the other end of the group by means of the interior canal.

In *Amaroucium* the fæcal or anal orifices, by which the common cloacæ open externally, are wide open during life, and easily perceived ; their form is round and their border thick ; but after death they contract, and are so much sunk in that they are demonstrated with difficulty.

The anal orifice in some genera is surmounted by a membranous languet, either simple or trifid (*fig.* 783. *i'*).

Fig. 783.



Anatomy of Botrylloides rotifera. (*After Milne-Edwards.*) *Lateral view of an isolated individual magnified.*

c, branchial orifice; *e*, branchial stigmata; *f*, thoracic sinus; *h*, cloaca; *i*, anal orifice; *i'*, supra-anal languet; *j*, nerve-ganglion; *k*, œsophagus, *l*, stomach; *m*, first portion of intestine, or duodenum; *m'*, second portion, or chylific ventricle; *m''*, third portion, or rectum; *n*, anus, opening into the cloaca; *q*, testicle; *r*, vas deferens; *t*, radiciform appendage, or proliferous stolon; *t'*, reproductive germs; *x*, liver (?); *x'*, its excretory duct.

In pointing out the natural groups of the associated Ascidians we have spoken of the division of the body into distinct portions, as the thorax, and super- and post-abdomen in *Amaroucium* (*fig.* 782.), and in *Polyclinum*, where they correspond to the three vertical chambers of the animal's cell ; and into the thorax and abdomen in *Didemnum*. The latter arrangement resembles that of the *Clavellinæ ;* but in the Botryllians, on the other hand, no distinct separation is observable, the viscera being pushed up by the side of the branchial sac, as in the *Perophoræ* and the simple Ascidians (*fig.* 783.). The thorax is generally more or less cylindrical, sometimes hemispherical (*fig.* 769.) or subglobose, and contains the branchial organs. In *Botryllus violaceus* there are two little glandular tubercles, one on the right and one on the left of the buccal orifice, and situated at a nearly equal distance from the superior extremity of the ventral sinus and the dorsal nucleus or nerve-ganglion.

The branchial sac of the *Botryllidæ* is very similar to that of the *Clavellinidæ*. The branchial spiracles, or intervascular spaces, are variable in number, and the crest or fold corresponding to the anterior border of the branchial sinus has no membranous languet ; but in *Diazona*, *Synoicum*, and *Polyclinum* it bears a row of minute tentacular filaments. The branchial sac of *Sigillina* has 4 large, salient, transverse vessels on each side, united by 15 or 16 smaller longitudinal vessels ; and in *Aplidium* there are 10 to 12 transverse branchial vessels. *Polyclinum* has 14 transverse branchial vessels anastomosing with 15 to 18 finer longitudinal vessels. In *Amaroucium* there are 10 to 12 rows of stigmata, and in *Polyclinum* 13 rows. *Didemnum* and *Leptoclinum* have 5 rows. In *Botrylloides* the respiratory sac presents 10 vertical rows of spiracles, parcelled into threes by vertical folds. There are 9 of these chink-like openings on each lateral rank, and at each of their four angles is a little tubercle. In *Botryllus* the respiratory sac lies almost horizontally, and has on each side 9 transverse rows of stigmata, grouped into threes by the longitudinal folds. The angles of the branchial net-work are marked with papillæ in *Distoma* and *Diazona*.

Instead of papillæ on the spaces between the branchial meshes, *Leptoclinum Listeri* has a thin ledge between each row of spiracles ; and in front there are three tapering moveable prominences, one connected with each ledge, either stretched forward horizontally into the cavity, or bent downwards with a spiral curve. These laminæ, observes Mr. Lister, seemed to suspend a generally invisible vertical membrane, and to assist in giving the food its direction towards the stomach ; for it moved horizontally along the sides of the cavity, as in *Perophora*, and when it reached the front, took a *spiral* motion downwards. When the branchial sac of the *Leptoclinum* contracted forcibly to reject what had been stopped by the tentacles, or found unfit for food, the oral orifice, instead of projecting, was then drawn down below the level of the external test, and depressed it, the cilia being also closely stretched across the openings of the spiracles. When the cilia were thus stopped in their action, they were seen to be very numerous, and being in close contiguity one with another, the neighbours by their sides, and the opposites by their ends, appeared almost as a continuous membrane.

The superior abdomen of the *Polyclina* contains the digestive apparatus, and the post-abdomen the organs of generation and the heart. The intestines of the *Botryllidæ* are always subject to one or more foldings, and their several portions are frequently distinguished by different tints of colour.

The superior abdomen in *Amaroucium* is short and rounded, and slightly separated from the thorax. The œsophagus is very short; the stomach in *A. proliferum* is marked externally with a series of vertical folds, the edges of which, seen under the microscope, are furnished with secretory follicles. In *A. argus*, the exterior of the stomach is coated with a tessellated series of irregularly hexagonal, gland-like, bodies, having the appearance of a number of minute honeycomb compartments, around each of which are radiating lamellæ or folds. In *Sidnyum* the stomach is also surrounded with glands; and in this genus the intestine is spirally folded. In *Diazona* the stomach is striated externally; its inner surface is provided with numerous salient folioles; and the pyloric entrance is guarded with an annular fold or valvule. The intestine in its first part is simply membranous, but afterwards it is furnished with irregularly disposed glands, which have the form of cæcal tubes. The stomach of *Sigillina* bears some slight ridges on its inner surface, the strongest of which correspond to external furrows. In *Aplidium* the stomach is somewhat oblong and truncate, and is divided by deep plications into three longitudinal cavities, or rather into five, the lateral ones being subdivided. The intestine is bent sometimes forward and sometimes backward; in the latter case it passes upward obliquely on the right side of the stomach; the rectum is sometimes spirally arranged, and sometimes straight. In *Polyclinum* also the intestine is spirally folded, obliquely traversing the left side towards the anal orifice. In *A. proliferum* and *A. argus* the rectum ascends to the middle of the cloaca. The post-abdomen is elongated, narrow, and tapering, divided from the digestive cavity by a marked constriction. The ovary occupies nearly the whole length of this cavity (*fig.* 782. *p*), and is partially surrounded by the glandular mass of the testicle, from which latter an undulatory *vas deferens* runs upwards to end in the cloaca near the termination of the rectum. The ova are whitish, yellow, or brown, and on escaping from the ovary appear to pass to the cloaca by the vacant space between the intestines and the interior of the mantle. The heart is a tubular vesicle, bent on itself, and situated at the inferior apex of the ovary.

In the *Didemnians* the digestive, generative, and circulatory organs are grouped together in the pedunculated abdomen, and offer nothing remarkable. The ovary is situated by the side of the intestine, and protrudes downwards only when full of eggs, which in this case have, when fully developed, a large size, compared with that of the animals. The mantle of the *Didemnum*, as in many other *Botryllidæ*, is frequently produced in the abdominal region into stolon-like processes, which traverse the common test. These swell at their extremities into reproductive buds, from whence arise new animals. Of these proliferous tubes we shall have to speak hereafter.

The stomach of *Botrylloides rotifera* (*fig.* 783.) is pyriform and divided into seven or eight lobes by furrows that pass horizontally from the cardiac to the pyloric extremity. The intestine is sigmoid, and is divisible into three portions; the first part is smooth and transparent, the second is surrounded with a granular tissue, and the third is membranous like the first. A glandular mass, apparently the hepatic organ, is situated at the commencement of the third portion of the intestine, and gives rise to many minute excretory ducts that soon unite into a single trunk, which appears to empty itself into the intestine near the pylorus. Below this organ and more behind, is another glandular mass, which apparently belongs to the generative organs, and gives origin to a little duct passing upwards to the cloaca. The heart is situated laterally, reposing on the cardiac side of the stomach. In *B. rubrum* the ovary is double, one part being situated on either side of the thoracic chamber. The testicle is seldom very distinct in the *Didemnina* and *Botryllina*, but has been occasionally observed.

The *nerve-ganglion* between the two orifices, or rather on the dorsal side of the buccal orifice, is generally more or less distinct in the *Botryllidæ*.

The *circulation of the Botryllidæ* does not materially differ from that of the other Ascidians, and has the same peculiar periodical change in the direction of the blood-currents. In the *Polyclinina* the heart is placed quite at the inferior extremity of the post-abdomen. It is invested with a thin, transparent pericardium, and has the form of a large contractile tube, bent on itself, and tapering at the extremities. In the *Didemnina* the heart is shorter, and instead of being situated beneath the ovary, it is lodged with that organ, by the side of the intestinal loop, this condition approaching that existing in the *Clavellinidæ*. Lastly, in the *Botryllina*, it ascends still higher, being seated near the stomach, nearly at the base of the branchial sac. Milne-Edwards, to whom we are indebted for the preceding facts, remarks that these different positions of the heart always coincide with analogous changes in the position of the ovarium. It is also the same, says he, in the simple Ascidians; and Cuvier was, without sufficient reasons, led to consider that the heart followed in its position that of the mouth.

If, says M. Edwards, we separate from the common test of any of the Polyclinian species a lively individual, and place it under the microscope with a little sea-water, the movements of the heart may be easily studied. The heart's contractions succeed each other somewhat regularly, but they are not brisk and extending at once through the organ, as in the generality of animals. The contraction commences at one of its extremities, and the narrowing of the tube is propagated in an undulatory manner towards the opposite extremity, in a manner somewhat similar to the peristaltic movements of the intestines in the higher animals. For some time the contractions follow each other somewhat rapidly, and have all the same direction; but suddenly they are arrested, and then recommence in a contrary direction. The blood thus sent sometimes from behind forwards, and sometimes *vice versâ*, ascends towards the thorax; but does not appear to be conducted thither by vessels. It is poured out between the inner tunic of the abdomen and the viscera lodged in that cavity; and here it forms currents, which vary in their position according as the movements of the animal, or any other mechanical causes, oppose their passage. In general, however, the chief portion of the blood ascends by the dorsal or the ventral surface of the abdomen; and after having bathed the surface of the viscera, it gains the base of the branchial sac. When the heart's contraction is from behind forward, the ascending current passes along the anterior side of the abdomen, and the blood enters a large vertical canal, on the front of the respiratory cavity, termed by Milne-Edwards *the great thoracic or ventral sinus*. This median sinus gives rise on each side to a series of large transverse vessels, which intercommunicate by means of a number of minute vertical vessels, and which, after having formed a kind of vascular network, spread over the walls of the branchial cavity, and terminate in another vertical canal parallel to the ventral sinus, but situated on the opposite side of the thorax. A portion of the blood arrives at the same time in this *dorsal sinus* without having traversed the branchial net-work, by means of a vessel that arises from the superior extremity of the great ventral sinus and surrounds the base of the branchial orifice. Lastly the blood spreads out between the viscera and the internal tunic of the body, descends along the dorsal side of the abdomen, and again reaches the heart. If the circulation were constant in the above direction, it would somewhat resemble that of the other Acephalans. The heart might then be compared to an aortic ventricle, the thoracic sinus to a great branchial artery, and the dorsal sinus to a branchial vein. But owing to the contrary directions of the blood-currents, from the periodically varying impulses of the heart, the vessels that fulfil at one time the functions of veins, at another become arteries, and *vice versâ*.

This peculiar extra-vascular circulation, so well described by Milne-Edwards, is also very distinctly seen in the *Clavellinæ*. The learned professor especially notices *C. nana* as highly illustrative of this phenomenon, the inter-abdominal space being in this case very large, and the currents of the nutritive fluid, with its suspended spherical globules, being easily discernible through the transparent integuments.

Mr. Bowerbank has favoured me with an account of some observations made by him on the circulation in the common tegumentary mass of *Botryllus*. Under the microscope, the more transparent portion of the test exhibited a reticulated arrangement of sanguiferous channels or vessels; perhaps the true "marginal vessels" of Savigny; each mesh, formed by the anastomosing currents, being occupied by one of the star-like "systems" of animals. No communication could be traced between the circulation and that of the animals themselves; the former appearing to be analogous to the peculiar stem-circulation of the polypifera, to which also the circulation of the nutrient fluid in the budless stems of *Perophora*, noticed by Mr. Lister, *vide suprà*, has reference.

Embryogenesis of the Botryllidæ.—In the development of the ova of the compound Ascidians, there are certain striking differences from the conditions that take place during the embryo-genesis of the *Ascidiadæ*. These, however, are chiefly confined to the composition of the egg, the formation of the Blastoderm, the mode of growth of the caudal appendage, the organs of vision, and the anterior appendages. From the elaborate observations of this family, given by Professor Milne-Edwards in his Paper before referred to*, it appears that the ova of several species of the *Polyclinina* are, whilst still enclosed in the ovary, and before that their development is much advanced, of an ellipsoid form, and are composed of a very thin external membrane, a subgelatinous whitish and granular inner mass, and a minute central vesicle filled with a watery fluid. The internal vesicle is the vesicle of Purkinje, or the proligerous vesicle; the granular substance surrounding the vesicle is the imperfect vitellus, the vitelline membrane being the external envelope.

Whilst these ova are still enclosed in the upper part of the post-abdomen, they grow rapidly and become spherical. But the most remarkable change that takes place consists in the colour of the vitellus, which is at first a pale, and afterwards a deep yellow. The vesicle of Purkinje is still visible at the commencement of this period of the development, but it soon disappears, and there then appears on the surface of the vitellus a nebulose spot of pale yellow, which appears to be the blastoderm or proligerous layer destined to become the embryo of the young Ascidian.

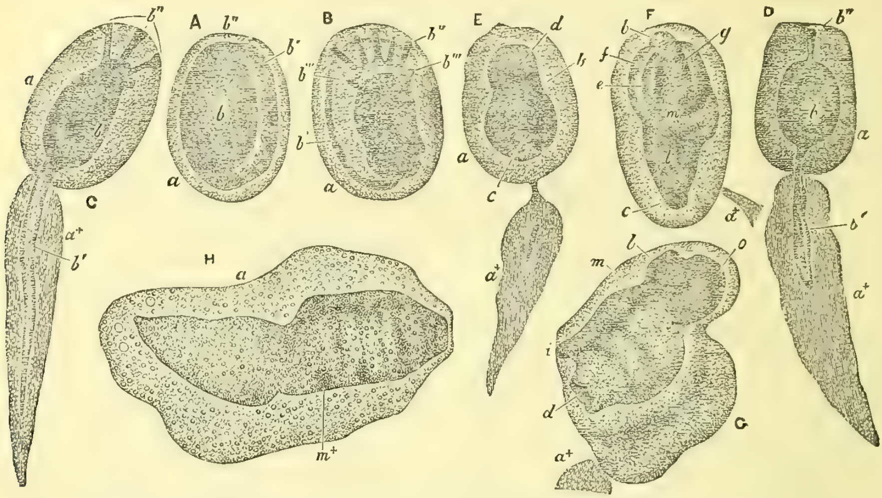
The ova arrive in the cloaca, and sometimes are even lodged in the lateral portions of the thoracic chamber, without having undergone any other appreciable modification. M. Milne-Edwards considers it probable that the fecundation of the ova takes place in the interior of this cavity. They are here brought into contact with the spermatozoa, and very shortly after having arrived here, they exhibit evidences of active internal changes.

The granules composing the vitelline mass become grouped into clusters, forming themselves, as it were, into balls, and giving the surface an embossed or mulberry-like aspect. At the same time there is formed between the yolk and the external membrane of the ovum, a gelatinous, transparent, and nearly colourless layer, which apparently becomes the external tunic or test of the young animal.

* Observations sur les Ascidies composées.

When the ova, lodged in the marsupial pouch or cloaca, have arrived at a rather more advanced period of their development, the vitellus loses the mulberry appearance it had but lately put on, and, if compressed between two slips of glass, it is seen to be wholly composed of minute globules or granules of different sizes. The ovum is soon a little flattened, and the yolk appears to be concentrated towards the middle, forming an ovoid mass of a deep yellow colour, surrounded by a somewhat large border of a clearer tint. This marginal portion of the yolk is condensed in its turn, and although at first sight appearing to constitute a sort of ring, becomes a long tapering prolongation, which encircles the central part of the yolk, adhering by its base, and having its pointed extremity free (*fig.* 784. A).

Fig. 784.



The Development of the Larva of Amaroucium proliferum. (*After Milne-Edwards.*)

A. *An ovum the incubation of which is far advanced, magnified about* 30 *times.* The tail, (b') is becoming distinct from the trunk (b); and two lobules begin to appear on the anterior extremity of the latter (b'').

B. *An ovum arrived at the full term of incubation, magnified about* 30 *times.* a, the tegumentary portion; b', caudal portion; b'', b''', anterior appendages.

C. *Larval ascidia lately born, magnified about* 25 *times.* a, tegumentary portion; b, sac enclosing the yolk and forming the proper tunic of the body of the larva; b'', processes terminating in suckers, and serving to fix the animal; a, tail formed by a prolongation of the integuments, and enclosing a tubular appendage of the vitelline sac.

D. *The same larva, observed some hours after having fixed itself, magnified about* 20 *times.* b'', traces of the anterior processes; b', vitelline prolongation of tail nearly absorbed, and the central sac, enclosing vitellus, is spherically contracted.

E. *The same larva about* 20 *hours after fixing, magnified about* 25 *times.* The caudal elongation of the internal tunic (containing the vitelline matter) has entirely disappeared, and this tunic (b) has taken the form of an ovoid sac, slightly contracted in the middle; a pale yellow circle (d) at the anterior extremity surrounds a spot that will become the mouth, and posteriorly another, clear, spot (c) appears, in which the heart will be developed.

F. *The same larva seen at the end of the second day of its sedentary state, magnified about* 25 *times.* b, tunic proper; c, pericardium spot; e, branchial sac, beginning to be developed; f, thoracic sinus; g, cloaca; l, stomach; m, intestine, full of fæcal matter; a, vestige of tail, of which a part only is figured. The external orifices are not yet formed. The development of this individual was much more rapid than usually is the case.

G. *Another individual, about* 8 *days old, magnified.* Animal completely reversed in the interior of the tegumentary envelope; d, oral orifice; i, anal orifice; l, stomach; m, intestine; o, heart.

H. *Individual about* 20 *days old, magnified* (lying with its anterior extremity to the right). a, tegumentary envelope; m, fæcal matter in the intestine.

In the course of incubation, the ovum increases in size, becoming flatter and more oval. The vitelline mass becomes more compact, and its surface denser; and the latter seems to be organised into a membrane, distinct from the yolk beneath. The two portions of the ovum, before described, become more and more separate; that which occupies the centre of the ovum becomes ovoid, and knotty at one of its extremities; near the other extremity, which is continuous with the marginal portion, are seen one or two blackish minute points. This ring-like portion is now seen to be a caudal prolongation, too short completely to encircle the central part, from which also it is distinctly divided a little in front. Lastly, the whitish substance surrounding the vitellus, and constituting the *tegumentary mass*, increases considerably in thickness.

When the ova more nearly approach maturity, the tail-part of the vitellus is shortened, and its central part, or body of the embryo, is more and more condensed. Its anterior extremity becomes lobulated and encircled with a series of five cylindrical processes, which have a divergent arrangement, and advance towards the border of the egg. Three of these appendages terminate in a kind of button, and the intervening two are tapering anteriorly.

At each side of the base of the group of tentacles, a little prominent lobular process is present. Lastly, the side of the body, opposite to that on which the tail is placed, becomes somewhat strongly embossed near its posterior extremity, and towards the space where the above-mentioned black points occur (*fig.* 784. B).

The ovum ready for exclusion differs apparently little from the foregoing state. The two anterior styliform appendages have almost entirely disappeared, and the three obtuse processes are further developed. The trunk is contracted towards its anterior extremity, and the yolk-mass still further condensed at the centre of the ovum.

The external membrane of the ovum becomes excessively thin, and then breaks and allows the embryo to escape. Generally this exclusion takes place in the interior of the cloaca, but sometimes not until the ova have passed out by the anal orifice. However that may be, the young animal, free from its envelopes, soon extends its tail, and swims in the ambient fluid by the aid of its undulatory movements. In its general form the young Ascidian resembles somewhat that of a newly born tadpole (*fig.* 784. C); but it still more resembles a *Cercaria.* The trunk or body of the larval *Polyclinum* is oval and rather depressed. The whitish tissue of the future integument occupies all the surface, and is considerably developed at the margins; its substance is granular and apparently subgelatinous; its consistence is greatest at the surface; and it does not appear to possess a membranous investment. Towards the centre of the trunk is a large elliptical membranous sac, the internal tunic of Milne-Edwards; this is filled with the yellow substance of the vitellus, and is continuous anteriorly with the three tubes dilated at the end, and terminating at the anterior wall of the egg in a sort of sucker. By means of gentle graduated pressure, some of the yolk may be easily made to pass from the principal sac into these appendages, and *vice versâ;* the little capsule, also, terminating each of these appendages can be made to protrude externally by the same means. At the base of these three processes the vestiges of the others formerly occupying the intervening spaces may be observed. The yellow substance contained in the internal tunic appears to be separated into two portions; the one is clear, and situated near the wall of this sac, and the other, denser and of a deeper tint, occupies the centre. Posteriorly a little marginal space, clearer than the neighbouring parts, is also visible, and on one of the sides the above-mentioned minute black spots are visible. The tail is very large, and, like the trunk, is composed of two distinct parts; the one superficial, colourless, diaphanous, gelatinous, and much resembling the albumen of the eggs of frogs; the other, central and yellow. This latter part is continuous anteriorly with the central sac of the trunk, and is also composed of a membranous tunic, enclosing a yellow granular and semi-fluid substance. It sometimes appeared to have a central canal. The larvæ, after swimming about with an active wriggling motion for a few hours, attach themselves to the surface of a solid body, and, if disturbed from their position, swim about as before until they meet with a similar situation. Their activity having ceased, they become permanently fixed, and are then about the size of the head of a very small pin. They appear to affix themselves to their resting place by means of one of the little suckers with which their anterior extremity is furnished.

The larva has now lost all power of locomotion, and quickly undergoes further changes of form. The anterior extremity of the trunk is widened, and the prolongations of the internal tunic quickly disappear. The central portion of the tail becomes at the same time empty, its contents being returned to the central yolk-mass of the body. The sac or internal tunic enclosing the yolk becomes much contracted and spherical; lastly, the yellow matter, which was unequally divided, seems again to be rearranged. The tail, which during the early period of the existence of the larva performed so important a part, being the only instrument of locomotion, is now reduced to its gelatinous or tegumentary portion; and this, after becoming more and more transparent, withers, and finally is detached, or falls away in shreds at a more advanced period of the growth of the animal. The trunk, on the other hand, is the seat of important and active changes. The tegumentary portion of the body is much widened, taking an oval outline, and is visibly augmented in bulk. The interior tunic continues at first to lessen, and becomes quite spherical, and many large patches of a lighter yellow than the rest are apparent, one of which occupies the anterior, and two others the posterior portions of the tunic (*fig.* 784. D).

M. Milne-Edwards further remarks, that the modifications already noticed ordinarily occupy the space of from ten to twelve hours; and if the larvæ are again examined towards the end of the first day of their sedentary existence, further changes in the interior tunic may be observed. In a specimen carefully watched by him, the following changes were noted. Instead of being spherical, the large yellow sac became oval, and its anterior part much thinned. It soon afterwards again became elongated, and a circular contraction divided it into two portions (*fig.* 784. E). The anterior portion, smaller and lighter coloured than the posterior, was rounded in front, and presented at that part a large annular patch of a deep yellow, vaguely circumscribing a central paler portion. The posterior part was swollen and of a deeper yellow than the anterior, and quite behind there was observable a minute patch of a very clear yellow. This latter spot subsequently became the *heart,* and the annular spot on the other extremity of the body was developed into the *thorax* of the animal. The following day all these parts grew still more distinct. The anterior portion of the internal tunic or the thorax, which had been smaller than the abdominal or posterior portion, was much increased, and far more diaphanous, and the part occupied by the whitish anterior spot was somewhat elevated in the form of a nipple, marking the future position of the mouth. The obscure circle that surrounded the base of the buccal region was now replaced by a very narrow yellow band; and on the inferior part of this thoracic portion of the body there were observed two yellow lines, vertically dividing it into three nearly equal lobes. The abdominal portion of the internal tunic was, on the contrary, much straitened; the pericardial spot was more distinct; and another less distinctly limited spot, situated more in front, presented apparently the first indication of the stomach. Towards the middle of the second day, the middle lobe of the thorax was much enlarged, and in certain positions of the animal appeared to be formed by a new interior cylindrical sac, which in front united with the anterior wall of the thorax at the point occupied by the yellow ring before described, whilst laterally it was separated from the internal tunic by the spaces corresponding to the lateral lobes already mentioned. One of these lobes became very much narrowed, and seemed destined to form the great vascular sinus: subsequently, traversing the anterior surface of the thorax, the other lateral lobe appeared to correspond to the future cloaca; and the middle lobe was evidently the branchial sac, from the base of which arises the digestive tube.

A few hours after, the anterior nipple-like prominence was more salient, and seemed to be contractile. The situation of the stomach and the course of intestine were also distinguishable in the abdomen (*fig.* 784. F). The yellow substance had now in a great degree disappeared, but it was still present in a pretty considerable quantity in the alimentary tube, and appeared to pervade all the interior parts of the young animal.

Towards the end of the second day, the branchial orifice was easily distinguished at the summit of the thorax, and its margin began to be somewhat crenulated. This orifice, however, was present only in the internal tunic, the tegumentary substance being continued over it without interruption. The nerve-ganglion appeared in the form of a minute tubercle. The yellow line encircling the summit of the thorax appeared as the superior margin of the branchial sac. All the thoracic portion of the body contracted itself from time to time. Lastly, the anal orifice began to be visible.

On the third day, the heart was seen to pulsate, and pellets of fæcal matter were visible in the intestine. The following day, the mouth opened externally, and the water passed through it to the branchial cavity. About the same time, the integument was perforated also by the anal orifice, from which fæcal matter was discharged, provided without doubt by the digestion of nutritive matter furnished by the vitelline mass (*fig.* 784. G).

On the following days, the growth of the young animal was more rapid, its organs became more distinct, and soon afterwards the spiracles of the branchial sac, disposed in transverse rows, were visible, as well as the vibratile movements of the cilia, with which the stigmata are fringed. The number of these rows, however, was but four, the adult animal having ten.

The young *Amaroucium* was now provided with all its necessary organs except those of generation, of which no trace was yet visible, and the future situation of which was occupied by other organs, the heart being close up to the intestinal tube. The general form of the body resembled more that of a Didemnian than of a Polyclinian, for it had as yet no post-abdomen, and the loop of the intestine was folded up against the inferior extremity of the thorax. Lastly, during the succeeding days, the abdomen very much lengthened itself (*fig.* 784. H), and at the end of the second week there was present, between the heart and the intestine, a granular mass, which by its appearance and position could readily be recognised as the generative organs.

With regard to the development of the *integument* of this, at first solitary, but subsequently compound, Ascidian, and which is evidently the analogue of the polypary of the *Polypifera*, we have mentioned that at first it is a gelatinous layer, surrounding the yolk. An inner membrane, immediately investing the yolk, and regarded as the blastoderm, becomes the internal tunic of the animal. Whilst the larva goes through its early changes, there appears no connection at all between the inner tunic and the integument. Indeed, says M. Milne-Edwards, the larva may be seen sometimes to be entirely turned round in the cavity of the tegumentary envelope; and sometimes, when it abandons its original position, it forms a kind of hernia on the exterior of this envelope, by distending it at a weak spot (*fig.* 784. G). The learned professor does not, however, regard this envelope as being either a deposit produced by secretion, or as an organised body that had ceased to live since it had ceased to be attached to the interior parts of the animal; because, as he observes, it continues to grow and gives unmistakable signs of vitality. Thus, not only does its bulk rapidly increase, but it frequently gives rise, as in *Amaroucium Nordmanni*, to lobe-like expansions, frequently changing their form, contracting and dilating very gently, and appearing to have some analogy to the proteiform expansions of the *Amœbæ* and other inferior animals. Of these changes Professor Milne-Edwards has given an interesting series of figures.

It is only when the mouth and the anus open externally, that an attachment is established between the integument and the internal tunic of the animal; and then, as throughout its future existence, it is around the two orifices only that organic continuity exists between the two parts, one only of which is in direct relation with the organs of animal life. It is consequently probable that the nutrition of the test is carried on by imbibition only; and M. Milne-Edwards points out the fact of the independence of these two portions of the body of these Ascidians during the early periods of their life, as worthy the consideration of physiologists; and he adds, that probably this kind of vitality of the integument of the larval Ascidians has some analogy with what obtains in Sponges, and may, perhaps, throw some light on the peculiar existence of the basilar portion of the *Sertulariæ* and other Polyps, that continue to live for some time after the loss of the soft parts that are generally, but wrongly, regarded as constituting the entire animal.

From observations made by the same naturalist on the development of the ova and larvæ of other species of the *Polyclinina*, and of the *Didemnina* and *Clavellinæ*, it appears that very similar modifications take place; the time occupied in the development being of course variable according to specific and external conditions. The larvæ of *Clavellina* have the internal tunic strongly lobed in front, very tumid behind, and destitute of the peculiar appendages observed in the *Polyclinina*. These appendages exist in the *Didemnina*, but are very short; and at their base are seen a row of pyriform lobules, which might easily be taken for the germs of young individuals, but all of which really belong to one individual.

The observations made by MM. Löwig and Kölliker on the embryogeny of some of these animals are generally in accordance with those of M. Milne-Edwards, but on some points, and especially with regard to the development of the *Botrylli*, there exists considerable discordance of opinion. The points involved being not only of interest, but of no slight importance, it is necessary to give in detail some of the most important observations recorded by the above-named naturalists.

In *Botryllus violaceus*, *B. aureus*, *Aplidium gibbulosum*, and *Amaroucium Nordmanni*, MM. Löwig and Kölliker observed, in the first stages of development, a division of the yolk similar to that taking place in the eggs of frogs, and described also by M. Milne-Edwards, and established also in the case of the simple Ascidians by Van Beneden. This division takes place as in the intestinal worms; that is to say, the simple nuclei, contained in the globules, which, as everywhere, are only aggregations of granules, always become double before the globules are divided in two. As soon as the division has arrived at a certain degree, the spherical form of the mass of globules becomes elongated, and takes more and more the form of an embryo, its tail making a semicircle about its body. The tail is distinct before any other part, and this, according to these observers, is evidently formed, not by an elongation of the embryo, but by the separation of a portion of the globules from the surface. In *Amaroucium* and *Aplidium*, at the same time as the exterior form of the embryo, and at a very early period, the two ocular points, remarked by Milne-Edwards, make their appearance; presenting as yet no trace of an envelope or of anterior processes. At a later period only is there formed around the embryo a transparent, colourless border, which, in *Amaroucium* and *Aplidium*, increasing more and more, especially at the thick end of the body, appears as a very strong lamina, but remains without structure all the time the embryos are contained in the membranes of the egg. Cotemporaneously with the formation of the envelopes, the embryos themselves commence also to undergo a series of changes. Firstly, towards the anterior extremity, there appear the three appendages of peculiar form; secondly, the yellowish substance in the interior of the body separates into two laminæ; the one, external, remains diaphanous; the other, internal, becomes opaque, and divides, in the *Botrylli*, into eight conical corpuscles, which surround a somewhat large, round, perforated nipple; lastly, a great number of structural modifications take place. The mature embryos of *B. aureus* are formed of a spherical body, 0·28‴ broad and 0·38‴ long, possessing an orifice surrounded anteriorly with three lobules, and posteriorly bearing a thin, tapering tail, 0·72‴ long. These embryos present exteriorly the thin, transparent, structureless layer (tegumentary layer) before referred to, from which almost solely the lobes, or lanceolate appendages of the head, are formed, and which terminate at the opposite extremity in a prolongation exceeding in length those parts of the tail enclosed within it. Interior to this, in the anterior part of the body, is a second delicate envelope, formed of cells either round or changed into fibres, which does not enter into the composition of the lobes of the head, but encases the mammillated prominence before described, and also the eight spherical bodies surrounding it, and is attached at one end to the edge of the nipple, and at the other to the interior part of the tail.

The internal substance, constituting the chief mass of the embryos, is, according to MM. Löwig and Kölliker, evidently a group of individuals, as M. Sars, who discovered those curious embryos of the *Botrylli*, has already shown. The eight spherical corpuscles, united at their bases, and provided with a kind of common stem, are so many individuals, and the prominent nipple situated in their centre represents the common excretory tube. This salient tube at its extremity has three lobules, which project into the base of the lobes of the exterior envelope: from its base three filaments (nerves?) arise, which passing upwards bifurcate each into two, one of which terminates at the orifice of the tube; the second reaches the summits of the lobules, and, passing beyond them, spread into five or six branches, extending almost to the edge of the lobes of the exterior envelope. In the eight embryos no orifice is perceptible, nor any other organs, except some canals (intestine) indistinctly rolled up. Their microscopic elements, however, are very distinct; namely, various-sized nucleated cells, filled with pale red granules and fibres in process of formation; the former constitutes the principal mass of the excretory tube. The internal part of the tail, which is apparently a direct continuation of the substance of the embryo, possesses an interior cavity, and its walls are composed of two layers of cells. The internal layer is formed of cells of 0·012‴ diameter, rectangular, with the angles slightly rounded, distinctly nucleated, and containing fine yellowish granules. They are very regularly arranged side by side in transverse series, so that the cavity of the tail is always surrounded by 10—12 cells. The external layer is composed of a continuous, simple layer, formed of minute cells, measuring 0·003‴—0·004‴, without any distinct arrangement. It is to be observed that this tail, formed simply of cells and a homogeneous envelope, exhibits very active movements, affording a new proof of the contractility of parts composed merely of simple cells.

The body of the embryos of *Aplidium* and *Amaroucium* is formed (at an early stage) of a thick, homogeneous, external layer, and a yellowish mass enclosed within it. In the spherical portion of the body, this mass is apparently wholly composed of round cells, of different sizes, and containing nuclei, and, towards the interior, probably unaltered globules produced by the division of the vitellus. These two elements do not compose any distinct organ; but only form two layers, one internal and opaque, and the other external and diaphanous. In *Amaroucium Nordmanni* there is no canal within the tail, but its centre is occupied by a simple series of large rectangular nucleated cells, producing a transversely radiated appearance, visible even when moderately magnified; the tail has also an external simple layer of minute cells, as in *Botryllus*.

Savigny, also, was led by his researches to regard both the ovum of *Botryllus* and that of *Pyrosoma* as giving birth to several individuals having already a certain order of arrangement. This view, in the case of the *Botryllus*, is, as we have seen, supported by Löwig, Kölliker, and Sars, and is considered by Van Beneden as founded on fact and supported by analogy. Milne-Edwards, however, is not disposed to admit this conclusion; for, in his opinion, the existence of the four embryos united in a circle in the *Pyrosoma*, and the development of a single star of germs in the larval *Botryllus*, do not sufficiently account for the association of many such groups in the adult age; there being, for instance, in the adult *Pyrosoma*, many hundred individuals of different degrees of development. Van Beneden thinks it probable that the presumed aggregate larvæ produce colonies similar to themselves by fissiparous reproduction; but Milne-Edwards gives it as his confirmed opinion that, from the single product of the ovum, the other associated individuals arise by *gemmiparous reproduction* only. Of this mode of generation in the *Botryllidæ* we will now proceed to give a slight sketch, again acknowledging the labours of the learned Professor of the Garden of Plants as the chief source of our information.

In *Diazona*, *Didemnum*, *Botryllus*, and *Botrylloides*, the common test is traversed by numerous ramifying prolongations of the inner tunic of the individual animals, terminating either simply in culs-de-sac, or swelling out into germs (*fig.* 785.). Savigny figured these

Fig. 785.

Vertical Section halfway through a Mass of Botryllus, magnified about 6 *diameters.* (*Original*).

a, animals on one of the exterior surfaces of the mass; *b*, proliferous stolons, traversing the mass, and bearing reproductive germs.

tubular bodies, and vaguely described them under the name of "marginal tubes" and "vascular branches." And Delle Chiaje*, in treating of *Polyclinium*, figures and describes "vessels" which are probably these ramifying canals. These membranous tubes, with their terminal vesicular enlargements, are readily seen during life in those species that possess a semitransparent test. Milne-Edwards observes that in *Botryllus* and *Botrylloides*, (*figs.* 785 and 783, *t*, *t′*), each of these interior appendages appears at first as a little tubercle on the surface of the abdominal portion of the inner tunic of the adult animal. The tubercle then becomes elongated, forming a tube, the free extremity of which is closed, its cavity communicating with the abdominal cavity of the animal from which it springs. The blood from the abdominal cavity circulates throughout this cæcal tube, with a very active double current. As the tubes lengthen, they generally become ramified, and soon present swollen or claviform extremities. The circulation continues active, and before long there is visible towards the summit of each terminal swelling a minute granular mass, the colour of which approaches that of the thorax of the adult animals situated close by. A little later this organised mass begins to present the form of a little Ascidian, and soon afterwards becomes a young animal, similar to those already occu-

* Memoirs, second edition, tom. i. p. 34. tabl. 83. figs. 13. and 15.

pying the common mass, of which it becomes a new inhabitant. The communication between the mother and the young animal becomes obliterated; but for some time yet, all the young individuals growing from the same branch remain united by their pedicle, and it is this union, apparently, that determines their mode of grouping into "systems."* In *Didemnum gelatinosum*, the buds growing on these proliferous stolons are very different in appearance from the ova expelled by the animals; for not only did they differ in aspect and form, but their bulk is at first twenty or thirty times less than that of the vitelline mass of the ova. In the *Amaroucium proliferum*, Milne-Edwards has frequently found on the surface of a rounded mass, formed by a colony of these animals, many little filiform twigs, simple or branched, formed by a prolongation of the common tegumentary substance, and consisting of a tube closed at the end, and enclosing, in its interior, one or more embryos in different states of development. These young individuals terminated inferiorly by a peduncle, prolonged in form of a slender tube into the common mass, and springing apparently from the abdominal tunic of an adult individual. This mode of propagation by buds, which the compound Ascidians possess in common with the *Polypifera*, is, as we have above described, found in the *Clavellinidæ;* the only important difference being, that in the latter the tegumentary envelope of the young is not so largely developed as in the *Botryllidæ*, and does not become fused with that of the adults; whence it results that the individuals springing from the same stem remain isolated, instead of being united into a common mass.

ANATOMY OF PYROSOMA. — The common tegumentary mass of *Pyrosoma* is semitransparent, subcartilaginous, toughish, and somewhat extensile. The exterior of the hollow, conical, or cylindrical body, formed by the aggregation of the individual *Pyrosomata*, is covered with numerous elongated tubercles, of a rather firmer consistence than the rest of the mass. Each of these constitutes one extremity of an individual member of the living group. The opposite extremity opens into the cavity of the cylinder, and is not free, but, like the trunk of the individual's body, is closely connected by the common mass with the similar parts of other individuals lying above, below, and on either side of it. In some species the animals are arranged much more regularly than in others, and appear to form piled-up rings or circles of individuals, more or less analogous to the otherwise disposed circular systems of some of the *Botryllidæ.* In *Pyrosoma atlanticum* the tubercles are simply conical, and are perforated terminally. In *P. elegans*, also, the external orifice of the individual opens at the extremity of the tubercle, and through it the water contained in the great cylinder has been seen to escape freely in little jets, when the Pyrosome has been taken out of the sea. In *P. giganteum* the tubercles are of various sizes, some being short and indistinct, and others, on the contrary, very much developed. The largest are conico-cylindrical flat, and lanceolate at the extremity, with the minute branchial orifice on the inferior aspect. This lanceolate extremity is crenulated on its sharp edges, and presents on its inferior aspect, between its point and the aperture, a slightly prominent keel. The branchial orifice is sometimes surrounded by a slight, free, crenulated membrane.

The interior of the great cavity is generally smooth. Its walls are perforated by the numerous minute anal orifices of the component individuals; and, at a slight depth, its surface is studded with a great number of yellowish, rose-coloured, or carmine spots, which are the hepatic and other visceral organs of the numerous animals. The terminal aperture of the large, conical, compound body of the *Pyrosoma* has, according to Lesueur and Savigny, a membranous border, which can be sometimes drawn together so as to close the cavity; and Mr. F. D. Bennett observed that, when first removed from the sea, the broader extremity of the cylinder presented a wide and circular orifice, forming nearly a continuous surface with the central tube; but when the animal was kept in a vessel of sea-water, or much handled, this orifice was closed by the contraction of a smooth, dense membrane at its margin, and which either obliterated the aperture, or left but a minute central orifice; water at the same time being contained in the barrel or tube of the body.

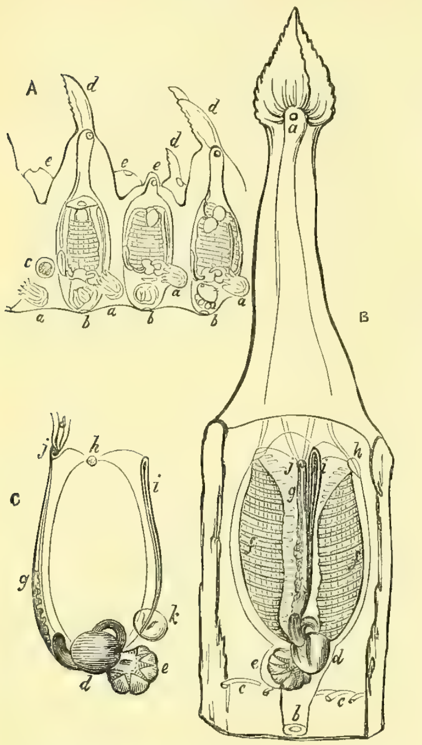
Besides the common envelope or test, each individual animal has an inner tunic or *mantle*. This is a very thin, delicate membrane, attached apparently at four points only, two of which are at the extremities; that is, at the branchial and anal orifices; and the other two are at two rounded, compressed bodies, one on either side, just beyond the anterior margin of the branchiæ, and regarded by Savigny as ovaries.

The *branchiæ* line the inner surface of this inner tunic. They are oval in form, and their dorsal borders meet each other, and are attached along the dorsal aspect of the mantle; but they are separated, at their anterior and ventral borders, by a considerable space, which is partly occupied by the ventral sinus (*fig.* 786. *i, i*). The branchial tissue is traversed by numerous vessels anastomosing with each

* M. Savigny figures a nascent system, originated apparently by this grouping of the buds; and Professor Van Beneden coincides with M. Milne-Edwards in the above view of the subject, but M. Steenstrup expresses his opinion that the mode in which the colonies and systems of the *Botryllidæ* are formed, is not sufficiently explained by this hypothesis; and, although (following Milne-Edwards) he considers M. Sars to have been misled in regarding the ova of the *Botrylli* as producing groups of animals, yet he is inclined to consider this grouping to be really a fœtal condition, but occurring in some hitherto unnoticed "aggregate" form of animal, produced from the "solitary" larvæ described by Milne-Edwards, just as the *solitary Salpæ* bring forth *Salpa-chains.*

other at right angles. The transverse vessels, varying from 18 to 25 in number, are the

Fig. 786.



Anatomy of Pyrosoma giganteum, magnified.

A. *A portion of the common mass with animals imbedded in its substance.* (*After Savigny.*) *a, a, a, a*, the liver; *b, b, b*, ova in the posterior cavity; *c*, ovum in the substance of the common test; *d, d, d*, full-grown individuals; *e, e, e*, undeveloped individuals.

B. *A single individual cut out of the common test, with a portion of the latter surrounding it, seen from below.* (*After Lesueur.*) *a*, branchial or external orifice; *b*, anal or internal orifice; *c, c*, delicate fibres traversing the test; *d*, stomach; *e*, liver; *f, f*, branchiæ; *g*, oviduct (?); *h*, ovary; *i*, ventral sinus; *j*, nerve-ganglion.

C. *The viscera of an individual Pyrosome.* (*After Lesueur.*) *d, e, g, h, i, j*, as in *fig.* B; *k*, ovum.

largest and most distinct, and are folded back on themselves at the free edges of the tissue. The longitudinal vessels are from 11 to 17 in number. "Nothing is more curious," says Milne-Edwards*, "than the respiratory apparatus of these little animals, when the vibratile cilia, with which each of the branchial stigmata is furnished, are simultaneously effecting their vorticiform movements with rapidity and perfect harmony."

The *œsophagus* is curved, and is of a bright red colour. The *stomach* is subglobular, yellowish, and opaque. The *intestine* is short, and strongly bent on itself; the anus is directed backwards towards the posterior orifice. The *liver* is a globular body, which is but slightly developed in young individuals; its postero-inferior portion is formed of several sections united by a centre, around which they converge, presenting the appearance of a flower with many petals, or a calyx with, most usually, 7, 8, or 10 divisions. The sections are not always equal. Their centre is occupied by a somewhat solid, granular substance, which they more or less perfectly enclose. Its colour is generally whitish, or of a light pink. It lies free in a cavity hollowed out of the test, and is attached by a membranous peduncle to the stomach, or rather to the intestinal loop (*fig.* 786. A, *a, a*, B and C *e, e*). These viscera are situated posteriorly to the branchial sac. By their disposition they leave a free passage to the water which traverses the branchial cavity. The *nerve-ganglion* is present at the anterior extremity of the dorsal border of the branchial sac. From it there proceed filiform branches towards the neck of the external tubercle and in other directions. The vessel or sinus that runs between the two free edges of the branchiæ is of considerable length, and has a slight general curve. It is divided, as it were, into four, towards its largest and anterior portion, or rather seems to be composed of two contiguous vessels bent upon themselves. These diminish in calibre as they run backwards, and, passing into a delicate filiform vessel, are lost near the stomach.

Two arching vessels, one on either side, pass from near the nerve-ganglion to the compressed oval bodies on the anterior lateral points of the branchiæ, and a similar pair of vessels unite these latter bodies with the extremity of the loop formed by the vessel that lies between the free ventral margins of the branchiæ. These four arched vessels form therefore a circlet around the anterior extremity of the branchial sac (*fig.* 786. B, *h*).

The *heart* is placed at the posterior part of the body, at the side of, and below, the visceral mass. Its character is perfectly analogous to that of the heart of other Ascidians. It contracts with the usual peristaltic movement, and changes periodically the direction of this vermicular movement, the vessels alternately playing the part of artery and vein.

With regard to the *generation of the Pyrosomidæ*, very little has yet been observed. Savigny describes as "oviduct" and "siphon-canal" the vessels that occupy the usual position of the dorsal sinus, running along the dorsal or superior surface of the branchial sac (*fig.* 786. *g, g*). They have, however, no apparent connection either with the presumed oviferous bodies situated at the anterior points of the branchiæ, or with the cavity posterior to the abdominal viscera occupied by the ova in Savigny's specimens (*fig.* 786. A, *b*). Lesueur discovered and described certain globular, transparent bodies in *Pyrosoma*, situated near the liver (*fig.* 786. C, *k*), which he regarded as ova; these were noticed also by Savigny. Each enclosed four minute Pyrosomes, symmetrically disposed, and readily

* Annales des Sciences Naturelles, sec. sér. tom. xii. p. 375. 1835.

recognised by the form and arrangement of their double branchiæ.

Whether the ova of *Pyrosoma* be always composed of four, or a greater or less number of young individuals, or whether they generally contain but a single one, it is still highly probable that *gemmiparous reproduction* obtains with these animals; the *fissiparous* mode, however, imagined by Péron as possibly occurring in the adult Pyrosome, is totally unsupported by evidence. The several stages of development in which the individual animals are found to exist in the common mass of the test, as noticed by Savigny, point to this conclusion; and possibly the delicate filaments regarded as muscular fibres by Savigny, first pointed out by the acute observer of these creatures, Lesueur, as traversing the test in a line with the abdominal cavities of the adult animals (*fig.* 786. B, *c*), may be the proliferous stolons as yet untraced throughout their course.

Phosphorescence of Pyrosoma. — M. Péron, who first discovered and established the genus, has given a lively description of the circumstances under which the *P. atlanticum* were first met with by him, in his Mémoire sur *le Pyrosome.** "We had," says he, "for a long time been detained by calms in the equatorial regions, between 19° and 20° long. west of Paris, and 3° and 4° north lat., the temperature of the sea being at the surface 22° Réaumur; and we could make no progress except by the aid of the short-lived storms peculiar to these climates. In the evening of the 13th Frimaire we experienced one of the strongest of these squalls; the sky was on all sides loaded with heavy clouds; all around the obscurity was profound; the wind blew violently; and the ship cut her way with rapidity. Suddenly we discovered, at some distance, a great phosphorescent band stretched across the waves, and occupying an immense tract in advance of the ship. Heightened by the surrounding circumstances, the effect of this spectacle was romantic, imposing, sublime, rivetting the attention of all on board. Soon we reached the illuminated tract, and perceived that the prodigious brightness was certainly and only attributable to the presence of an innumerable multitude of largish animals floating with the waves. From their swimming at different depths they took apparently different forms; those at the greatest depth were very indefinite, presenting much the appearance of great masses of fire, or rather of enormous red-hot cannon-balls; whilst those more distinctly seen near the surface perfectly resembled incandescent cylinders of iron.

"Taken from the water, these animals perfectly resembled each other in form, colour, substance, and the property of phosphorescence, differing only in their sizes, which varied from 3 to 7 inches. The large, longish tubercles with which the exterior of the Pyrosomes was bristled were of a firmer substance and more transparent than the rest of the body, and were brilliant and polished like diamonds. These were the principal seat of phosphorescence. Between these large tubercles, smaller ones, shorter and more obtuse, could be distinguished; these also were phosphorescent. Lastly, in the interior of the substance of the animal, could be seen, by the aid of the transparency, a number of little, elongated, narrow bodies (viscera), about a millimètre in length, which also participated in a high degree in the possession of the phosphoric light.

"The colour of the animals, when at rest or when moribund, was observed to be of an opaline yellow, mingled with a disagreeable green; but during the spontaneous contractions of the animals, and which were also easily excited at the pleasure of the observer, the body seemed to burn, becoming instantly like molten iron, with an extremely bright light; but, as the phosphorescence again ceased, the colour of the animal passed successively through a number of extremely agreeable, light, and varied tints, such as red, yellow, orange, green, and azure blue, the last shade being extremely lively and pure.

"Left to itself in a glass of sea-water, the Pyrosome exhibited at regular intervals of time a slight alternating movement of contraction and dilatation. In these movements, the phosphorescence was seen to be developed during the contraction, then to grow insensibly feebler, and entirely disappear, until in the next contractile movement it was quickly re-established.

"By often irritating the animal, either by touching it or by shaking the water in which it floated, the phosphorescence could be excited and maintained for a much longer time. Evidently dependent on the organisation and the life of the individual, after death, as is the case with all other phosphorescent marine animals, it could not be reproduced."

We may remark that the observations made by Mr. F. D. Bennett*, who more than once met with shoals of *P. atlanticum* in lat. 1° 41′ N., long. 11° 56′ W., and lat. 4° S., long. 18° W., differ but slightly from M. Péron's notices of the same animal. The former observed, that when the specimens were taken in the hand from a vessel of sea-water, the whole mass of the animal became instantly illuminated by myriads of bright dots, much resembling in hue the points on the wing-cases of the diamond-beetle; and that the small specks of a brown or red colour, that were imbedded in the general tissue, and intermingled with the prominent, rigid, pearly tubercles, appeared to him to be the chief seat of the phosphoric light, frequently remaining bright, whilst the remainder of the body exhibited only its naturally white or yellowish hue—a hue which changed after death into a red tinge. In making a close examination of the animal, Mr. Bennett remarked that no luminous matter was communicated from the surface of the animal to

* Annales du Muséum d'Hist. Nat. tome iv. 1804.

* Proceedings of the Zoological Society, 1833 and 1837.

any fluid or solid in contact with it. But if the *Pyrosoma* were cut open and immersed in water, the brown particles that escaped diffused themselves through the fluid, and shone as numerous scintillations, independent of the perfect structure. General friction or contact was not essential to elicit the perfect light of the Pyrosome, since touching one small portion of the body was sufficient to produce a brilliant glow throughout the whole.

Mr. Bennett at the same time made the following observations on the effect of fresh water on phosphorescent marine animals. "Fresh water appears to act as a powerful and permanent stimulus on marine *Noctilucæ*. Those that have intervals of repose from their phosphorescence immediately emit light when brought into contact with fresh water; and this fact was strikingly exhibited in the *Pyrosomata*. When placed in a vessel of sea-water and permitted to remain quiet, these Molluscs afforded no light, and, when touched, gleamed forth only as long as the irritating cause remained, and then gradually returned to their original state. When, however, the same creatures were placed in a vessel of fresh water, they never ceased glowing with their brightest refulgence until life was extinct, which was not until the lapse of several hours. When also the same Molluscs were mutilated, or so near death as to refuse to emit light upon irritation in sea-water, immersing them in fresh water produced at least a temporary revival of their brightest gleam."

Anatomy of Salpæ. — The subcartilaginous test of *Salpæ* is more or less cylindrical and flexible, and when taken out of the sea, often collapses into an amorphous mass. Floating in the water, it is iridescent or opaline, reflecting the sun's rays in beautiful rainbow tints, and hence has been derived its name of "sun-fish." The test and its lining membrane are so diaphanous, that the whole structure of the animal can be seen through them. The exterior of the test is generally smooth, but sometimes bears minute shiny protuberances of a tissue similar to its own, as in *S. Tilesii*. The integument over the viscera is thicker and often of a firmer consistence than the rest of the test. Its form varies considerably, not only in different species, but in the conditions of isolation and aggregation, in which each species alternately exists, and also in the different stages of growth of the individual, especially in an associated state.

The test is usually either oval or oblong, but various terminal and lateral processes considerably affect its general contour. Each of its extremities is open by an orifice; and, in the aggregated individuals, it is perforated by other much smaller apertures at the points of contact between the neighbouring individuals of a group.

The internal surface of the test is lined by the *mantle*, a thin, toughish membrane, which is often more conspicuous than the highly transparent external envelope. The mantle is furnished with large, generally transverse, muscular bands, the arrangement of which differs according to the species and according to the separate or associated state of existence. Its inner surface is lined with a soft mucous coat of fine epithelial tissue. The mantle is more or less closely attached to the inner surface of the test, especially at the two orifices (being, indeed, continuous with the test at these points), at the protuberances that arise from the test, and along the inner surfaces of the longitudinal furrows that sometimes traverse its external surface, as in *S. cordiformis*, where, on the superior and inferior surfaces, the test is depressed into broad, deep sulci. In specimens preserved in spirit, and even in some recent specimens, this membrane will sometimes separate itself, together with the viscera and vessels, from the outer tunic, and fall through one of the external orifices. *Salpæ* have been met with floating in the sea, and executing, in some degree, their usual movements of contraction and dilatation; in which, from mutilations caused by parasites or other accidents, little remained except a few muscular bands of the mantle.

Considerable confusion has existed among naturalists as to which is the anterior extremity, and which the superior surface of the *Salpa*. We shall regard, as the anterior or branchial orifice, that in the neighbourhood of which the stomach and heart are usually found (*fig.* 787.); and as the posterior or anal orifice, that which points in the direction of the animal's retrograde motion; and as the superior or dorsal surface, that on which the nerve-ganglion is present; and as the inferior or ventral, that in close contact with which the viscera and heart, forming the "nucleus" or "*paquet*" of authors, are placed.

The orifices are either terminal, or are situated at the base of the terminal prolongations of the test. The anterior orifice is destitute of tentacular appendages; it is furnished with sphincter muscles; it is simple and tubular in *S. cristata*, *S. Tilesii*, and *S. scutigera*, &c., and transverse in *S. cordiformis*, *S. zonaria*, &c. When the dilatation of the animal is drawing water into the cavity of the body, the sphincters of this orifice are brought into action and close it, so that the water enters by the opposite extremity.

The posterior orifice is a transverse slit, furnished with a few muscular fascicles, and is larger than the opposite orifice. In *S. cristata* its superior lip is simple and thin; its inferior lip is externally a rounded ridge, formed by a fold of the test, which, within its inner border, constitutes a semilunar valve. This allows the water to enter easily, but prevents its escape when the animal contracts itself.

The constrictor muscles of the mantle are often subannular, interrupted on one or the other surface, decussating in some, connected in others. The following are a few examples of the disposition of these muscular bands. In *S. cristata*, around the tubular anterior orifice, are 4—5 sphincter muscles; the first of which, as well as the last two, are continuous around the tube. The last two send lateral processes backwards, forming, with the succeeding band, the first on the trunk, and also annular, large rhomboidal meshes ; two other annular bands succeed and form large meshes by intercommunications on the upper and lower surfaces. From these last muscles two intercommunicating processes are sent off on each side to the crestlike prominence of the test. From the last band several branches run backwards to be distributed to the upper and lower lips of the posterior orifices.

In *S. Tilesii* the anterior orifice is provided with two lateral penniform muscles. The other muscles form six bands nearly parallel with each other, interrupted along the median line of the superior surface, and not reaching further than halfway down the sides of the body. The most anterior band is somewhat forked, and the most posterior gives some branches to the superior lip of the posterior orifice, and joins, at the angle of the lips, a radiating group of other fascicles, that are distributed to the inferior lip.

In *S. scutigera* the muscular bands are few. On the superior surface, two pairs of decussating muscles are seen, and other smaller bands occur near the extremities. In *S. cylindrica* there are eleven transverse bands, interrupted and separated by a considerable space on the inferior surface of the body ; the first six of which are parallel one to another, whilst the four following are bent towards each other on the median line of the body ; the last band, and some short lateral fascicles, are arranged close by the posterior extremity. In *S. fusiformis* there are seven transverse bands ; some of which are parallel with, and approaching others on the sides of the animal, and others are more or less obliquely arranged. In *S. cordiformis* there are six broad transverse muscles on each side of the animal, not meeting on either surface. Two narrow, looplike fascicles, one above and one below, arising from the last branchial bands, and two short, transverse, lateral slips, act as sphincters to the posterior orifice. A pair of narrow muscular fascicles are sent off from the first of the branchial muscles to the anterior orifice. In *S. zonaria* (the aggregate form or "*proles*" of *S. cordiformis*) there are also six transverse bands interrupted only on one surface, and differing considerably from those of *S. cordiformis*, as do the distinct sets of muscles distributed to the two orifices. In *S. runcinata* (solitary) (*fig.* 772. A) the muscular bands are nine in number, placed on the dorsal surface ; three anterior and three posterior, approximated at their centres, and three parallel bands in the middle. In *S. runcinata* (aggregate) (*fig.* 772. B) there are six muscles, besides those of the orifices ; four anterior and two posterior, approximating on the median lines.

The *branchia* is single, in the form of a riband-like tube, stretched, on a vertical plane, obliquely across the central or branchial cavity of the body, so that it is constantly bathed by the water traversing this cavity. It consists of a double membrane formed by a fold of the internal tunic or mantle, and springs anteriorly from the visceral nucleus between the œsophageal opening and the orifice of the rectum ; it then becomes free, and ultimately terminates on the superior part of the thoracic cavity, below the point where the nerve-ganglion and the oculiform organ are found. It thus divides the branchial cavity into two portions — the antero-dorsal or pharyngeal, and the postero-ventral or cloacal.

The inferior border of the branchia exhibits an infinite number of minute transverse vessels, all parallel to each other. There is usually only a single row of these transverse vessels on each side of the foliole of the branchia ; but sometimes there are many rows, which indicate the presence of many longitudinal vessels, and thereby approach the character of the branchial tissue of the Ascidians.

Savigny observed in *S. octofora* another small branchia near the anterior insertion of the large branchia.

The whole inner surface of the branchial sac of the Salpæ seems, from its high degree of vascularity, to be subservient to the purposes of respiration. The vascular tissue of the branchia, consisting of longitudinal and transverse vessels, is equivalent to the vertical branchial network dividing transversely the respiratory cavity of the *Clavellinæ*.

The single branchial lamina of *Salpæ* appears to constitute the transition from the *Ascidiæ* to the *Teredines;* in the latter there are two elongated branchial laminæ above the intestine, and within the tubular mantle, to which the water has access and egress by means of two tubes placed at the posterior extremity of the body.

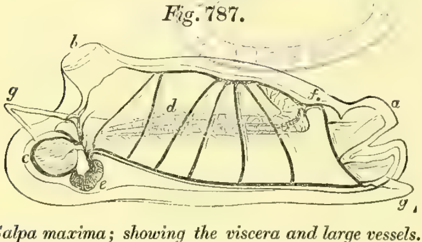
The *intestinal canal* is opaque, fuscous, or variously tinted, generally closely folded or convolute, and sometimes enveloped in the liver, forming altogether the "visceral nucleus." This, together with the heart, lies external to the mantle, between it and the test. The œsophageal aperture is in the antero-inferior part of the body, behind the heart, more or less conspicuous and variously modified; dissimilar in the alternate "proles" of the same species. In the solitary "proles" of *S. pinnata* and *S. affinis* it is stretched above the branchia. In the aggregate "proles" of *S. pinnata* it is opened out longwise, and of a violet colour in the living specimen.

In *S. cristata* the intestinal canal has the following characters. The œsophagus is round, with a loosely plicated margin ; the stomach has a contrary direction to the rest of the canal, being a cul-de-sac pointing anteriorly, and situated in the thickness of the antero-inferior protuberance of the test. It is membranous and transparent, and is described by Cuvier as ordinarily containing a little greyish fluid. The intestine is a simple tube having a direction unusual among the Salpians ; it runs from the stomach towards the posterior extremity of the body, where it opens into the branchial cavity by a rather large anus. The fæcal matter contained in it is greenish and vermiform. The liver (testicle, Krohn) in this species appears to be composed of large, parallel, longitudinal filaments, and terminates posteriorly in a delicate, tapering point. It differs also from the liver of other species in being of a whitish colour.

The intestine of the Salpians is usually twisted once or twice either around or within the liver, with the anus terminating nearly free of the latter, near the anterior attachment of the branchia. The anus is generally on the left side, opening posteriorly. The rectum never traverses the heart. In *S. gibbosa* and *S. infundibuliformis* the intestine makes a little more than one turn, the two ends crossing one another a little. It has two cœca, one on each side, which are turned into the centre of the loop of the intestine. Eschricht describes the liver of *S. zonaria* as conspicuous, enveloping nearly all the alimentary canal, and consisting of a mass of cœcal tubes, each of which bear, near their free extremities and on one side only, a group of 2—6 minute, short cœcal appendages.

The *heart* is with difficulty observed in dead specimens, but, from its pulsating movements, is generally conspicuous in the living animals; and in these only can the circulatory apparatus be traced out. It is situated in the antero-inferior region of the body, near the visceral nucleus, the anterior attachment of the branchia, and the generative organs. It is a somewhat long, pellucid, tubuliform vesicle, enclosed in an immoveable pericardium. A longitudinal vessel or sinus (aorta, of Van Hasselt) traverses the inferior surface of the branchial cavity, and is continued into the inferior lip of the posterior orifice, and into the base of the posterior prolongation (if present) of the test. Hence it is retroflexed and recurrent. It gives off numerous branches at right angles on either side (*fig.* 787.) from which arise

Fig. 787.



Salpa maxima; showing the viscera and large vessels. The fine vascular net-work of the branchial sac is not introduced. (*After Milne-Edwards.*)

a, upper lip of posterior orifice; *b*, anterior orifice; *c*, abdomen, containing the visceral nucleus; *d*, branchial lamina; *e*, heart; *f*, oculiform point; *g*, *g*, prolongations of the test, by which the animal is adherent to its neighbours.

a great number of smaller branches, that subdivide, anastomose, and spread out in different parts of the body, forming a fine vascular network. All the transverse canals open into a large dorsal vessel, which thus receives all the blood which has passed through the vessels of the branchial sac; but, besides this, some blood is also received by it, which has not passed through this tissue, in consequence of the great dorsal vessel being connected at each extremity with the great thoracic or abdominal vessel by two considerable annular vessels. The blood returns downwards from the dorsal vessel through a canal lying on the dorsal surface of the abdomen (dorsal canal) to the opposite end of the heart. The vascular net-work is very conspicuous in *S. aspera*, and is sometimes particularly distinct in the appendages. These ramifications go off from one another at right angles, and afterwards are, for the most part, bent back archwise, as Chamisso and Van Hasselt have observed; so that, with the exception of those running transversely, all these little vessels have a direction contrary to that of the principal vessels; that is to say, they are directed from behind forwards, whilst the aorta runs from before backwards. At the anterior extremity of the heart are two vessels, that answer to the pulmonary veins (dorsal sinus). They are equally distributed in the body of the animal, anastomosing with the branches of the principal sinus (aorta). The circulation of the blood among the viscera is carried on by means of variable interspaces occurring between these organs. The motions of the heart are made spirally, by a twisting of its parietes, and always begin from one or other of its extremities. As in other *Tunicata*, this action is oscillatory, having an alternately contrary direction, first impelling the blood in one direction, then stopping, contracting again, and soon impelling it in an opposite direction; so that, after the blood has been flowing for some time from the heart to the aorta, to be distributed to the body, it stops, and then begins to run by the arteries and the aorta to the heart, and from thence, by the pulmonary veins and their anastomoses, it returns into the arteries and aorta. The contractions of the heart, in general very regular, diminish in rapidity at the approach of the periodic change in the circulation, the blood stopping, and even retreating a little until a general contraction of the body determines it to take an opposite direction. The duration of the opposite circulation is not always the same. Van Hasselt saw the blood flow for three-fourths of a minute from the heart to the aorta; and, during this time he observed forty-two contractions of the heart; and he saw it reflow from the arteries to the heart and the pulmonary veins for a third of a minute, and in this interval he counted sixty-two pulsations.

The motion of the blood is the more perceptible as it is full of minute white globules, which pass through the minute vessels in a single row, and are easily seen through the transparent parietes. These observations may be still more assisted by holding the animal vertically, with the nucleus downwards; when, as the blood, driven into the ventral sinus, is forced to ascend against its own weight, its current is less rapid, and the movements of the blood-discs can be more easily followed. "As these blood-globules are of a certain consistence, a resistance," says Van Hasselt, "is necessarily created in the whole mass of the blood, which ultimately overcomes the projectile power of the heart. After a short interval, during which the opposite forces are balanced, the heart assumes a spiral movement, contrary to the preceding. Hence it follows," he observes, "that, since the blood is driven as much backward as forward in the vessels of the body, and since it is only by their anastomoses that the circulation can be said to be carried on, all the system of the pulmonary vessels can consist only in accessory ramifications, which have no direct influence on the principal circulation; and that two separate systems, arterial and venous, do not exist, the two being united, or rather never having been separate."*

The *nerve-ganglion* is more or less developed in all the Salpians. It is situated on the superior surface of the thoracic chamber, near the posterior extremity, and just above the insertion of the branchia. In its neighbourhood is often observed a pigmentary spot, or rudimentary organ of vision.

In *S. cordiformis* the ganglion appears as a compound body, formed of two central globular portions and four irregular lateral appendages, two on a side. Numerous filaments radiate off in every direction. Four of these filaments are sent towards the posterior orifice, two of them passing on either side of the space described by Prof. Eschricht as the "oval organ." This latter is a long slit with an inner smooth rim, and an outer oval, transversely striated border. In *S. zonaria* the ganglion is a somewhat triangular, globose body, with a single appendix on each side, sending off four anterior filaments, two lateral pairs and a posterior pair. The "oval organ," situated between the last pair, is close up to the ganglion, and less distinct than in *S. cordiformis*.

Many of the *Salpæ* are highly *phosphorescent* †; but sometimes this condition is due to the presence of phosphorescent Crustaceans inhabiting their internal cavity. The long chains of phosphorescent *Salpæ* swimming near the surface, have been described as occasionally producing the effect of long ribands of fire drawn along by the currents.

Generation of Salpæ. — "One of the most important discoveries," says M. Krohn‡, "with which physiology has been enriched in our days, is without contradiction that of the remarkable phenomena observed in many inferior animals, and termed, 'propagation by alternate generations.'" To M. Steenstrup* the merit is incontestably due, of having been the first to bring together, in an ingenious manner, all the facts belonging to the subject. In treating of the phenomena observed by Chamisso in one species of *Salpa*, and analogous phenomena studied in other groups of animals, and in his generalisations of the facts, M. Steenstrup has placed them in a strong light, and given them their full value. M. Steenstrup's observations have also tended to strengthen the views of Chamisso † so often contested; and the researches of M. Krohn, on the natural history and zootomy of eight species of *Salpæ*, fully confirm them.‡ Every Salpian is viviparous; and each species, as shown by Chamisso, is propagated by an alternate succession of dissimilar generations. One of these generations is represented by solitary or isolated individuals; the other by aggregated or associated individuals, united into groups known as "chains." Each isolated individual engenders a group of aggregated individuals, and each of these produces in its turn a solitary individual. The isolated individuals are therefore multiparous, and the associated individuals uniparous. This is not the only difference existing between the two alternating generations; for, if we compare the associated individuals representing the aggregate generation, with the solitary individual forming the isolated generation, we shall find that they differ amongst themselves not only with respect to external conformation, but also in many particulars of organisation.

The definition, then, of species should in this case include the characteristics of the two dissimilar generations, isolated and aggregate, which alternately succeed each other. It is desirable therefore, for the determination of each species, to preserve but one name. This

* Extrait d'un Lettre de Van Hasselt, sur les Biphores, le 12 Août, 1821 (Algem. Konst-en Letterbode, 1822). Annales des Sciences Naturelles, tom. iii. 1824, p. 78. Bull. des Sciences, tom. ii. p. 212.

† See Mr. G. Bennett's Observations on the Phosphorescence of the Ocean, "Proceedings of the Zoological Society, 1837;" and his "Wanderings in New South Wales." See also the Article, LUMINOUSNESS, ANIMAL.

‡ Observations sur le Génération et la Développement des Biphores. Annales des Sciences Naturelles, 3e série, tom. vi. 1846.

* Ueber den Generationswechsels in den Niedern Thierklassen, 1842.

† De Animalibus quibusdam a Classe Vermium Linneanâ. Fasc. 1. "De Salpâ." Berolini, 1849, 4to.

‡ M. Steenstrup, in his memoir on the Alternation of Generation (edit. Roy. Soc. pp. 39 and following), gives a full account of the different views of Chamisso, Meyer, and Eschricht, with regard to the development of the *Salpæ*. He allots considerable space to the consideration of the arguments of the learned Danish professor, with whose opinions, however, he does not coincide, acknowledging that all his own researches tend to support the observations of Chamisso.

M. Steenstrup notices that the alternate generations of *Salpæ* are precisely analogous to the phenomena observed in the propagation of *Medusa aurita*. This free-swimming *Medusa* always produces a progeny which is polypiform and destitute of the power of locomotion, but which ultimately brings forth, by fissiparous generation, a progeny consisting of free-swimming *Medusæ*, which never assume the polypoid form; and this alternation is constant. M. Sars observes, on the generation of *Salpæ* (Erichson's Archiv. 1841, t. i. p. 29.), that "the *Salpæ* correspond in this with the *Medusæ*, that it is not their *larvæ* which are developed into the perfect animal, but the *progeny of the larvæ*; it is not the *individual*, but the *generation*, which is metamorphosed."

must comprehend the two dissimilar states which have hitherto been falsely considered as two distinct species, and to which have been given specific names, that can now serve only to designate one or the other of the heteromorphous conditions.*

Amongst the characters that distinguish the different generations of each species of *Salpa*, one of the most remarkable is offered by the disposition of the muscular bands. These are variable in the two generations, but constant for each of them. There is, however, a still more essential difference, and that is, the mode of propagation peculiar to each generation. The *aggregate* individuals proceeding from the isolated individuals grow by gemmation within the mother animals, on a cylindrical prolongation, which may justly be termed a proliferous† stolon, but which differs from stolons observed in many other animals, in not ever appearing externally. — The stolons of the "social" Ascidians spring up bare, the animal not being connected by a common gelatinous envelope, as is the case with the "compound" Ascidians ; in which latter group the stolons necessarily remain hidden in the common envelope, somewhat approaching in this respect the stolons of the Salpians.

The *solitary* Salpians derived from the aggregate generation are, on the contrary, produced by a process more complicated namely, by means of the sexual functions,—the concurrence of the eggs and the sperm.

Generation in the "aggregate" Salpians. — With very few exceptions, the individual aggregate Salpians produce only one offspring throughout their life‡, so that, if we examine them at one period, anterior to fecundation, we find a single egg, and, at a later period, a fœtus. The *egg* is distinctly visible within the young aggregate individual before it has left its parent (isolated) Salpian ; and as the fecundation of this egg takes place immediately, or at least a very short time after, the birth of the young aggregate Salpa, it can be examined before fecundation, that is, during the development of the aggregate within the isolated individual, or shortly after its birth. The egg is lodged in the thickness of the internal tunic of the mother, at a little distance from the inner wall of the respiratory cavity. It is very clearly distinguishable in the aggregate embryo at a period intermediate between the appearance of the solitary embryo as a bud and its full development. It is then situated above the visceral mass, at the *anterior* extremity of the body, and nearly in the middle line, raising the external tunic into a slight prominence. It is spherical, and consists of a vitellus, containing the germinal vesicle and spot, and invested with a membrane so thick, that M. Krohn is led to regard it as comparable with the "calyx" in birds. During the progress of the development of the animal, the position of the egg is altered, and it becomes situated on the side of the body, somewhat approaching towards its superior surface, and behind the second muscular band. This position is retained by the egg, and subsequently by the fœtus.

To the posterior extremity of the egg a cord is attached, which serves as a sort of peduncle, in general directed nearly horizontally backwards, and consisting apparently of a prolongation of the membrane that covers the vitellus. At the period when the egg occupies the anterior extremity of the embryo, this cord is proportionally thicker and shorter than at the subsequent periods of the embryo's development. M. Krohn considered it as being the nutritive peduncle of the ovarian capsule, or membrane, enveloping the egg. This cord exists, as above described, up to the time of fecundation, but it soon afterwards disappears. The ovary, we see, is

* To the above observations, M. Krohn has added the following list of such species of *Salpa* as he had been enabled to recognise in the two states: —

Species.	In the Solitary State (*Proles solitaria*, Chamisso).	In the Aggregated State (*Proles gregata*, Chamisso).
1.	Salpa democratica, *Forskahl*; S. spinosa, *Otto*	Salpa mucronata, *Forskahl.*; S. pyramidalis, *Quoy* and *Gaimard.*
2.	Salpa africana, *Forskahl*	Salpa maxima, *Forskahl.*; S. Forskahlii, *Lesson.*
3.	Salpa runcinata, *Chamisso*	Salpa fusiformis, *Cuvier.*; S. maxima, var. prima, *Forskahl.*; S. runcinata, gregata, *Chamisso.*
4.	Salpa, observed by *Krohn*	Salpa punctata, *Forskahl.*
5.	Salpa scutigera, *Cuvier*; S. vivipara, *Péron* and *Lesueur*; S. gibba, *Bosc*; S. dolium, *Quoy* and *Gaimard*	Salpa bicaudata, *Quoy* and *Gaimard.*; S. nephodea, *Lesson.*
6.	Salpa, observed by *Krohn*	Salpa proboscidalis, *Lesson.*
7.	Salpa cordiformis, *Quoy* and *Gaimard*	Salpa zonaria, *Chamisso.*; S. polycratica, *Forskahl.*
	The recognition of the two forms of this species was made by Prof. Eschricht, and confirmed by M. Krohn.	
8.	Salpa costata, *Quoy* and *Gaimard*; Dagysa strumosa, *Banks*	Salpa Tilesii, *Cuvier.*; S. infundibuliformis, *Quoy* and *Gaimard.*

M. Krohn observes also, that Salpa ferruginea, *Chamisso*; S. confæderata, *Forskahl;* S. socia, *Bosc;* S. octofora, *Cuvier* (?); S. lævis, *Lesson*, and S. femoralis, *Quoy* and *Gaimard*, do not materially differ from S. bicaudata.

† Professor Eschricht was the first to recognise the true signification of this part.

‡ *S. zonaria* is the only example of an aggregate *Salpa* producing several (four) fœtuses.

represented merely by the membrane that surrounds the egg, and which, as before remarked, may be compared to the *calyx* of birds. The testicle, on the contrary, is well developed, but, not increasing in bulk in proportion to the growth of the young Salpa, it only acquires its greatest development in nearly adult animals. It is always found in the neighbourhood of the intestine, but its position varies in different species. Sometimes occupying the centre of the visceral mass or nucleus, formed by the intestinal loop and its appendages, its presence is evident only in proportion as it raises those parts; sometimes showing itself quite exposed, it more or less covers a large portion of the digestive apparatus. This organ in the aggregate form of *Salpa pinnata*, *S. proboscidalis*, &c. is spindle-shaped, and rests against the intestine, and has been taken for the liver by Cuvier, Chamisso, and Meyen. The testicle is composed of a greater or less number of ramified canals, the last ramifications of which end in culs-de-sac. All these canals end in a principal duct, which, passing along the terminal portion of the intestine, opens at the side of the anus in the great natatory or respiratory cavity traversing the body of the Salpa.

The testicle is very much slower in its development than the egg organ in these animals; and, as young aggregate Salpians are met with in which a fecundated egg and undeveloped testicle are co-existent, these individuals must have had connection with others in which the development of the latter organ was further advanced; the sperm that fecundated the eggs being supplied by another group of animals. The maturity of the sperm does not coincide with that of the egg, yet, as the two sexual organs are present in the same body, these animals are hermaphrodite, although probably not self-impregnating. They have two generative functions to perform: the one to produce a new being, the other to fecundate an ulterior generation of animals similar in all respects to themselves. The "aggregate" Salpians probably perish soon after they have given birth to their "isolate" offspring.

The placenta, or attachment of the fœtal "isolate" in the "aggregate" Salpæ.—The embryos of the *Salpæ*, undergoing all the phases of development within their mother, adhere to her by the aid of an organ, the use of which is to furnish them with the necessary nutritive elements. These elements being derived from the blood of the mother, the vessels of the latter enter largely into the composition of this organ. Its structure and form vary much according to the mode of propagation peculiar to each generation. The propagation in the "isolated" Salpians is by gemmation, and here the organ in question is the *proliferous stolon.* In the "aggregate" Salpian, on the other hand, this organ is represented by a body generally round, situated on the inferior surface of their single fœtus, and fixed to the internal wall of the maternal cavity, precisely in the position occupied by the egg, and to this organ many naturalists have with reason attributed the functions of a *placenta.* This placenta is ordinarily situated in the external tunic of the fœtus; its structure is far from being well known. In appearance it is a soft, whitish, or brownish pulp, traversed by numerous vessels; it is attached by a very short pedicle, which is formed by a prolongation proceeding from the inner tunic, and enveloping this organ. The vessels distributed in the interior of the placenta communicate with four trunks, two of which communicate with the vascular system of the fœtus, and the other two with that of the mother. Those of the fœtus, in descending towards the placenta, traverse the peduncle; the one conducting the blood to this organ, and the other returning it to the fœtus. The two maternal trunks have analogous functions; they terminate at the point where the placenta is attached to the mother. Each of these fœtal and maternal trunks alternately act as arteries and veins. This alternation is due to the periodic changes that determine the contractions of the heart in Tunicates generally. The vessels of the fœtus and of the mother are not in direct communication; but, as in *Mammalia*, they are merely contiguous. M. Krohn's microscopical observations also tend to prove that the maternal blood never commingles with the fœtal blood. The blood-corpuscles of the fœtus are distinguishable from those of the mother by their less size and by the more constant regularity of their forms.

The development of the placenta commences at any early stage of enbryonic life, and in its progress corresponds to that of the fœtus. Ultimately the placenta becomes detached from the maternal tissues, and is carried away by the young born animal. It remains for a long time in connection with the young animal, but decreases rapidly in size, and ultimately disappears before the full growth of the animal is perfected.

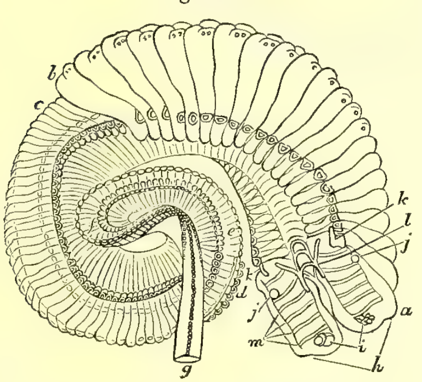
Eleoblast of the fœtal Salpæ. — There is another organ belonging to the fœtus, mentioned by authors, especially Chamisso, Meyen, and Krohn, which is a round whitish body, lodged, like the placenta, in the external tunic of the fœtus. Its use is entirely unknown. It appears to be composed of a multitude of fascicles or lamellæ, that, by their intercrossing with one another, circumscribe cellular cavities, filled with a perfectly clear oily liquid, composed chiefly of globules. The fascicles or lamellæ are traversed by numerous vessels opening into two trunks, which apparently form the attachment between this organ and the visceral nucleus. Meyen thought it to be the vitelline sac of the fœtus; but, according to M. Krohn, this opinion is inadmissible, because the "aggregate" embryos, which we know are not produced from eggs, are provided with it. This body, M. Krohn terms the "eleoblast." During the incubation of the fœtus, and after the birth of the individual, the changes of volume undergone by this organ correspond in general to those of the placenta; but its decrease proceeds more slowly, and its remains are observable long after the placenta has disappeared.

Development of the fœtal "isolate" Salpæ. — The development of the fœtal "isolate" Salpa occupies a considerable time, not being accomplished until the mother has almost attained her full growth. Of the progress of the genesic phenomena, there is as yet but little clearly known. The first changes manifest in the egg after fecundation, are the early disappearance of the germinal vesicle and spot, the increase of the egg in size, and the loss of its ovular, and assumption of a spherical, form. Soon afterwards the egg, so transformed, is replaced by a round body, which raises the internal tunic of the mother into a slight nipple-like prominence, projecting into the internal cavity of the latter. This is the rudimentary placenta, and is channelled by a cavity which is in direct communication with the two maternal vessels previously spoken of. These vessels are at this period very minute, but they quickly increase in size. By their means a current of blood is already established in the interior of the rudimentary placenta. The maternal blood carried by one of the vessels of the cavity rises on one side towards its base, and then, describing an arch, descends on the other side, to return to the mother by the opposite vessel. The first rudiment of the fœtus is, it seems, developed after the appearance of the placenta. It is at first a very minute body, formed on the summit of the placenta and under its envelope: this covering is a continuation of the internal tunic of the mother, and becomes, at a later period, the external tunic of the fœtus. The organs soon appear in the rudimentary embryonic mass. The respiratory cavity, M. Krohn observes, is, probably, one of the first parts formed, the fœtus, previously solid, becoming evidently hollow; immediately afterwards the rudiments of the branchia and the nervous ganglion are perceptible; the visceral nucleus, the eleoblast, and the heart become distinct only at a late period. When the eleoblast is developed, it is placed anterior to the visceral nucleus, and the heart then begins to contract, although feebly. It is only when the fœtus acquires a better determined form, that the two orifices of the body become visible, the posterior at an earlier period than the anterior. The fœtus now surpasses the placenta in volume, although the latter has not, since its appearance, ceased to grow; and the nervous ganglion, distinguishable from all other parts by its rapid growth, is conspicuous from its volume, compared to that of the other organs, and gives origin to numerous nerve-filaments. The eleoblast, the volume of which is considerably increased, tends to place itself below the nucleus. It is at this period also that we can clearly distinguish the muscular bands, although in a yet imperfect state. Each band is represented by two lateral symmetrical portions, separated one from another by a large interval along the superior surface of the body; it is not until a later period that the two portions are united into a single band. The placenta also exhibits a marked change. The cavity that it contained disappears, and its place is occupied by the pulpy whitish substance before spoken of. At a more advanced stage, but still far from the full term of development, the fœtus presents a form that subsequently is but little altered. Its volume, compared with that of the placenta, is greater than before. The eleoblast, as yet less than the placenta, is now placed behind it, and soon equals it in size. The distribution of the vessels on the different parts of the fœtus is become more apparent; and the two trunks enclosed in the peduncle of the placenta are distinguishable. Now also the contractions of the heart may be seen to change their direction periodically, the blood consequently circulating in the same singular manner as in the adult Salpians. But another still more remarkable phenomenon manifests itself at this period, viz. the precocious formation of the *stolon proliferum*, which springs from near the heart, in the form of a little button.

During the later periods of development, the resemblance of the fœtus to the adult becomes more marked daily, as well as its increase of volume compared with the placenta. The fœtus, which in the last period referred to already showed some indication of spontaneous movement, commences to alternately contract and dilate its body, like the adult animal. These movements, feeble at first, are before long, as the animal approaches its full term, executed with considerable vigour. The fœtus being attached to its mother, these movements cannot displace it; and their only end, without doubt, is to draw towards it the supply of water necessary for its respiration. As regards the *stolon proliferum*, its growth during all this time is so slow, that, even at the time of the birth of the animal, it is but a short, delicate filament. Nevertheless, on a close examination, there may be perceived on its surface a serrated edge of minute elevations, indicating the first vestiges of the buds that will subsequently be developed into embryos.

Generation in the "isolate" Salpians. — The "isolate" Salpians are, as we before mentioned, gemmiparous, and have their young produced on a small pedunculated organ, the *stolon proliferum*, which is visible within the single fœtus whilst still contained within its "aggregate" mother. It then exists as a very slender short filament, but already gives indications of buds upon its surface. After the birth of the animal, it increases in size in proportion to the continually increasing number of buds that spring from it. It is fixed by one of its extremities to the heart of the mother: and it is always at this extremity that the stolon produces new germs. The growth of the buds, just as the nutrition of the embryos, being entirely dependent on the blood of the mother, the stolon is constructed to admit a proportional quantity of the vital fluid. Two vessels traverse it throughout its length, one proceeding from the anterior extremity of the maternal heart, and the other from the opposite end. Hence the blood, forced into one of these vessels by the contraction of the heart, returns by the other; and at each time the heart commences to contract in an opposite direction, the two vessels quickly coincide in the change. M. Milne Edwards has demonstrated that the proliferous stolons of the social and compound Ascidians are likewise traversed by two similar vessels, one of which has an ascending current of blood, and the other a descending current. In examining the stolon at a more advanced period of its growth, one may embrace at a view, owing to the successive germination of buds, the complete series of the phases passed through by each embryo, from the time of its first appearance in the form of a little button, to the full term of its development (*fig.* 788.). The

Fig. 788.



Salpa zonaria (*aggregate*) *in its fœtal state. Magnified about* 4 *times.* (*After Eschricht.*)

a, b, part of the first set of the young Salpæ; *c, d,* the second set; *e, f,* the third set; *g,* the stem with its germs; *h, h,* the anterior orifices; *i, i,* viscera; *j, j,* ganglia; *k, k,* posterior orifices; *l,* vessels; *m,* muscular bands of the branchial sacs.

phases passed through by the different organs correspond to those that the same organs present during the development of the "isolated" fœtus.*

Development of the fœtal "aggregate" Salpæ within the "solitary."—Whatever may be the mode of aggregation of the associated Salpæ at the adult age, their germs are always disposed in the same pattern along the stolon in two parallel rows, so that the germs alternate one with another. It necessarily follows that the embryos during growth must be arranged in the same manner. The embryos are always placed in such a manner that the axes of their bodies cross the axis of the stolon at a right angle: they adhere among themselves by means of their organs of attachment. The development of the "isolate," like that of the "aggregate," fœtus proceeds but slowly: the growth of those fœtuses that spring from the first-formed germs is not terminated until after the mother has almost attained her full age. It is easily conceived that, as the number of buds continues to augment during all the time the mother grows, the form of the germs and the embryos, or the embryonic chain, acquires lastly a considerable length. Lodged in the external tunic of the mother, and adhering to the heart of the latter by the aid of the vessels of the stolon, this embryonic chain sometimes passes directly backward, and terminates before reaching the posterior extremity of the body, as in the isolated generation of *Salpa pinnata* and some allied species: sometimes, as in most other species, it curls itself around the visceral nucleus, describing several spiral turns, and terminates at the anterior extremity of the body. If we examine the embryonic chain at this period, we may observe three very distinct groups of embryos (*fig.* 788.). The proximal group (*f, e*) is made up of the germs and of the embryos, as yet but little developed, that succeed them. These present a progressive series of the early phases of embryonic development; but the next group (*d, e*) is composed of embryos much further developed, and these being nearly all of the same size, offer but a slight trace of gradation. The distal group of embryos (*b, a*) having arrived almost at their full growth, present no great difference among themselves. The embryos, products of the same stolons, leave the mother in groups, and the group most developed is necessarily the first to be born. The perfect uniformity in the size of the newly born individuals explains also why the animals of Salpa-chains are all of the same size and form. The embryonic chain of *S. pinnata*, however, and allied species, never presents these distinct groupings. Here, on the contrary, the phases of development proceed regularly, following the order of progression throughout the chain. Hence the newly born animals, grouped in a circle, are often somewhat unequal in size; but this irregularity soon disappears.

The embryonic chain, as we have seen, is lodged in the external tunic of the mother. During the earlier periods of its growth, the substance of the tunic envelops it so closely, that no interval is apparent between them; but, as the mass of embryos increases in size, there is formed around it, and chiefly around the most fully developed group of embryos, a cavity which is prolonged towards the surface of the mother's body, and opens externally by a large orifice. By this orifice the embryos, when mature, make their exit. The position of this opening always corresponds with the point where the embryonic chain happens to terminate, which is sometimes near the anterior extremity, but sometimes even at the posterior extremity of the body of the

* The development of the fœtal "aggregate" Salpians is beautifully illustrated in the fourth and fifth plates of Prof. Eschricht's Paper on the Salpæ, in the Royal Trans. Copenhag. vol. viii. 1841.

mother. At the moment of the birth of a set of embryos, they detach themselves from that part of the stolon which supported them, and it then withers and disappears.

The embryos, as we have seen, are placed along the stolon in such a manner, that the axes of their bodies cross the axis of the stolon at right angles. This original position of the individual either persists from birth throughout life, or is changed, accordingly as the new-born animals belong to one or other of the three types of aggregate form to which the associated Salpes are hereafter referred. In the associated *Salpæ* of the first type, the relative position of the individuals remains such as it was at birth. In the Salpians of the third type, however, a change of position of the young individuals is very manifest, for the form of the generality of these Salpians is not quite perfected at birth. The two pyramidal processes with which the bodies of *S. maxima* and *S. fusiformis* are furnished, are but slightly developed in the newly born animals. The growth of these prolongations during youth is accompanied with marked changes in the position of the respective individuals of the group. When these processes are but small, the body of the animal is slightly inclined to the axis of the chain. This direction becomes the more oblique as the two prolongations increase; and lastly, when they have attained their full growth, the animal is perfectly parallel to the axis of the chain; and now the development of the "aggregate" Salpian is accomplished.

Mode of arrangement and attachment of adult "aggregate" Salpæ. — Each group of aggregate *Salpæ* is composed of a greater or less number of individuals of the same size. Sometimes the individuals are grouped in a simple circular series around a common axis, as in *S. pinnata*, and some allied species. Sometimes the individuals are arranged one after another in two longitudinal, parallel series, and so disposed that the individuals of one series alternate with those of the opposite series (*fig.* 772. c). The biserial aggregation presents numerous variations, according to the diversities and forms peculiar to the associated individuals of different species. In these diversified modes of assemblage, M. Krohn points out three types, to which all the variations are reducible. The first is characterised by the vertical position of the animals forming the chain, so that the axes of their bodies cross the axis of the chain at a right angle (*Salpa bicaudata*, *S. ferruginea*). In the second type the bodies of the individuals are more or less inclined to the axis of the chain (*S. mucronata*, *S. Tilesii*). The third group is distinguished by the horizontal position of the component animals, the axis of their bodies being more or less parallel to the axis of the chain (*S. maxima*, *S. fusiformis*, *S. punctata*, *S. zonaria*).*

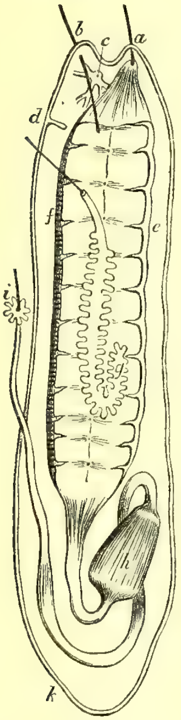
* Meyen also made an analogous distribution of the aggregate Salpians. *Vide* Nova Acta Nat. Cur. tom. xvi. "Supplementum."

In each group the individuals are in such close approximation, that there exists no interval between them, and the entire group appears as one mass. The individuals touch one another by the inferior surface, and more or less also by the lateral surfaces of their bodies. The superior surface, that where the nervous ganglion is situated, and the two orifices, remain perfectly free. Thus, for example, in a chain in which the individuals are disposed vertically or obliquely to its axis, the members of each rank are united to those of the opposite rank by their inferior surfaces, and to their collateral neighbours by their lateral surfaces. But, however closely the individuals may adhere one to another, mutual contact of the surfaces would not have been sufficient to maintain their juxtaposition, had not other appliances been furnished. There are sometimes appendages of considerable size, sometimes small protuberances, or only circumscribed points of the surface of the body, by the aid of which the animals adhere among themselves so strongly, that they can rarely be separated without some effort. These special organs and facets of attachment have been very incorrectly regarded by some authors as suckers. Their number varies according to the mode of aggregation. The associated individuals of *Salpa pinnata* and allied species, grouped in a circle, are provided with only a single large appendage, springing from the inferior surface of the body, and resembling sometimes a crest (*S. pinnata*), sometimes a horn (*S. proboscidalis*). The individuals, few in number, are united by the extremities of these appendages, which meet one another in the centre of the group. The organs of attachment of *Salpæ* aggregated in chains are protuberances and facets, generally about eight in number. Four are placed in pairs on the inferior aspect of each animal, and serve to unite it to its two neighbours in the opposite series; of the two other pairs, one pair occupies one of the lateral faces, the other the opposite lateral surface, uniting the individual to its two collateral neighbours. The position of these organs varies according to the form of the associated individuals, and accordingly as they belong to one or the other of the above mentioned types. Of these appendages we may notice the two prolongations of the body common in most of the aggregate forms of the third type, as in *S. maxima*, *S. fusiformis*, and chiefly by means of which the contact of the individuals is preserved. Both are pyramidal in form, and arise one from the anterior and the other from the posterior extremity of the body.

We will here remark that an individual cannot spontaneously separate itself from the group of which it forms a part. It is true that free individuals are often met with, but their separation is always due to some accident. M. Krohn thinks even that the union in groups is so necessary to the maintenance of the life of each animal, that it soon perishes if by chance it becomes detached.

Anatomy of Pelonaia.* — *Muscular system.* — The mantle is similar to that of other Tunicates, possessing longitudinal and circular fibres; the former in *P. corrucata* forming a thick bundle at their origin round the respiratory opening. A strong band of transverse fibres passes round it, in one species, immediately below the anal orifice, encroaching on the cavity principally on that side. The chief peculiarity of the mantle is its firm adhesion to the test.

Fig. 789.



Anatomy of Pelonaia glabra. (*After Forbes and Goodsir.*)

a, a bristle inserted into the respiratory sac through the oral orifice; *b*, a bristle inserted into the mantle cavity through the anal orifice of the test; *c*, ganglion, with the nerves proceeding from it; *d*, the shelf, or transverse ridge, in the interior of the test and mantle; *e*, branchial vein, enclosed in a serpentine band, as in some of the other Ascidians; *f*, branchial artery; *g*, generative organ on the left side, with a bristle inserted into its duct; *h*, the stomach; *i*, anus; *k*, *k*, cut edge of the test.

Digestive and respiratory systems. — The respiratory opening is of small size, and exhibits no folds or tentacular fringes. The respiratory sac is elongated, cylindrical, contracting rather suddenly towards one side to become continuous with the œsophagus. On the external surface of the sac there are about thirty parallel transverse ridges, which give it the appearance of a plaited frill. These plaits are less apparent along the course of the branchial artery and vein, but midway between them on each side they are very prominent, and are tied, each by a minute cord, to the inner surface of the test. The internal surface of the sac exhibits along one side the serpentine double cord which contains the branchial vein; along the other side the branchial artery; and from these primary and secondary perpendicular branches proceed, as in other *Tunicata.* The transverse plaits on the external surface of the sac correspond to the primary or transverse branches of the vessels on the internal surface. During the life of the animal, without doubt, cilia exist in great abundance on the edges of the lozenge-shaped spaces of the sac.

The œsophagus commences by a white plicated opening at the lower end, and on one side of the sac (*fig.* 789.). It is curved in a sigmoid form, and exhibits longitudinal rugæ through its coats. Near the lower end of the mantle-cavity it terminates by suddenly dilating into the stomach (*h*), which is pear-shaped, and directed obliquely upwards towards the side opposite to the œsophagus. The internal surface of the stomach presents longitudinal plicæ. It is succeeded by the intestine, which at first curves upward, and then down to the bottom of the branchial cavity, up along the œsophageal side of that cavity and between its walls and the branchial artery, terminating about the anterior third of the animal in a funnel-shaped anus (*i*), which is cut into ten or eleven processes, like the petals of a flower. The first part of the intestine is white, and longitudinally plicated; the rectum is dilated, and its coats are attenuated.

Vascular system. — The vascular system resembles that of the *Ascidiadæ*, except that there is no heart. It consists of two sets of vessels, with four sets of capillaries; a circle in fact twice interrupted, once in the respiratory sac, and again throughont the body. The branchial veins run along the transverse plaits of the sac, receiving secondary and ternary twigs at right angles. The primary branchial venous branches empty themselves on each side into the branchial trunk, which runs in the substance of the double cord which coasts the superior aspect of the sac. This double cord terminates in an abrupt manner anteriorly near the oral orifice, and in a similar manner, but often becoming smaller near the orifice leading to the œsophagus. At this point the vein becomes an artery, and probably sends back vessels to nourish the sac. It now runs along the œsophagus, supplying the stomach and intestine, and giving off in its course branches to the mantle. The veins arising from the arterial capillaries of the body meet near the commencement of the œsophagus in one trunk, which, passing along the inferior wall of the respiratory sac, opposite to the branchial vein, performs the functions of a branchial artery. It is interesting to observe here the differences between the modes in which the branches enter the branchial vein, and strike off from the branchial artery. In the former, just before the

* From Forbes and Goodsir, *loc. cit.*

branches enter the trunk, they give off a number of vessels, which enter a trunk alongside of the parent trunk, the combination forming a sort of delta; in the latter, they leave the trunk singly, and send off their branches in a radiating direction. At a little distance from the trunks of both artery and vein, the secondary branches become parallel to one another and perpendicular to their primary branches, the more minute divisions following the same mode of ramification.

Nervous system. — This system consists, as in other Tunicates, of a ganglion situated in the substance of the mantle, between the oral and anal orifices. It is globular, and sends off nervous twigs, firstly, to the respiratory orifice of the mantle; secondly, to the respiratory sac, where it begins to exhibit the transverse plates; and thirdly, to the anal orifice of the mantle.

Generative system. — The generative organs consist of two elongated tubes, closed at one end, open at the other, and having a great number of close-set parallel cœca arranged at right angles, and opening into them along each side. These tubes are attached to the internal surface of the mantle; their mouths are free for a short distance, and prominent the rest of their extent, and the attached cœca adherent. The orifices of these organs are situate at the junction of the first with the second quarter of the animal, and one third of the other end of each turns in towards its neighbour, and then proceeds forward parallel to itself. The branchial vein runs midway between the generative tubes above, and the branchial artery in a corresponding course below, so that the threads of the attachment of the plaits on the external surface of the sac are fixed into the tubes in a series on each side.

From the details of the structure above given, it is evident that the *Pelonaia* is a true Tunicate. Its anatomy is important, and assists in the elucidation of the nature of the parts and organs in other members of the group. They present the positive anatomical character of a union of the mantle with the test; so that there can be little question of their right to be regarded as members of a distinct family of *Tunicata;* and it is worthy of notice, says Prof. Forbes, that Mr. MacLeay, in his valuable remarks on the arrangement of the Tunicates (Linnæan Transact. vol. xiv.) had hypothetically indicated such a group as this now constituted. Whilst in many of their characters they approach the true Ascidians, especially the unattached species of the genus *Cynthia*, in others they indicate a relationship with the cirrhograde *Echinodermata*. They differ from their Tunicate allies chiefly by their not being fixed, and by their form, which reminds one more of that of a *Siphunculus* than of an *Ascidia;* indeed, they may be regarded as analogous to certain *Siphunculidæ;* and in that point of view the details of their form and structure are of much interest to the naturalist. They differ also, add Messrs. Forbes and Goodsir, from the Ascidians, more particularly in being bilateral. The generative organs are symmetrical, and open one on each side of the anus, which is directed towards the ventral surface of the animal, in a line with the mouth and the nervous ganglion. The latter is thus proved to be an abdominal or subœsophageal ganglion, corresponding to or forming one of the chains of ganglia on the abdominal surface of the *Articulata*. In the same manner, the branchial artery or heart is proved to be the pulsating dorsal vessel, and the branchial vein the abdominal vessel (when that vessel exists) in the *Annulosa*. It is interesting also to perceive, that, co-existing with this decided approach to the annular type of form, we have the transverse plaits of the respiratory sac corresponding to the rings of an articulated animal. The disappearance of a separate test is also a departure from the plan of formation in the *Ascidiadæ* and their allied groups, and an approach to other types of form, and more particularly to the cirrhograde Echinoderms, with certain of which *Pelonaia* has at least an analogical relation, in the water-filled body, and in the external form.

Pelonaia, in fine, is one of those connecting genera so valuable as filling up gaps in the system, and supplying links in the chain of structures which runs through the series of organised bodies.

Locomotion of Tunicata. — Generally speaking, the muscular tissue of the *Ascidiadæ*, *Botryllidæ*, and *Pelonaiadæ* is not subservient to the purposes of locomotion, and merely effects the sudden removal of water and noxious objects from the branchial sac. The entrance and exit of water through the external orifices, constituting the chief sign of vitality in these apathetic creatures, are generally caused by the ciliary currents.

But the water may be driven out by an ejaculatory effort of the constrictor muscles of the mantle; which action would be followed by a more or less rapid expansion or dilatation of the mantle and test, effected by the elasticity of the latter. In such species as occasionally occur unattached, or even floating about freely, such an ejaculatory action would effect a transitory retrograde movement; but we have no evidence that any of the *Ascidiadæ* or *Pelonaiadæ* make use of this propulsive agent in the manner of the *Pyrosomata* and the *Salpæ*. Nearly all the *Ascidiadæ* and *Botryllidæ* are sessile, but some few, mounted on flexible pedicles as *Boltenia* and *Sigillina*, may be said to enjoy a limited freedom of movement, necessary perhaps to their well being; and the same may be said of such species as are attached to the floating branches of flexible algæ and corallines.

According to Mr. F. D. Bennett, except in the action of the sphincter-like membrane, surrounding the open extremity of the compound cylinder, there was but very slight evidence of motive power in the specimens of *Pyrosoma* examined by him. MM. Péron and Lesueur, however, describe a slight retrograde motion observable in this animal. The method in which this is brought about is not very clear ; it appears to be caused either by the synchronous contraction of the individual animals, causing a diminution in the general calibre of the cylinder, and thus effecting a faint ejaculation of water from the cavity of the latter ; or by the posterior current of water from the anal orifice of each animal being synchronously ejected into the cavity of the cylinder, and thus giving a motive power to the whole.

We have a more decided locomotion exhibited in the *Salpa*, which is treated of by Mr. Bishop* as a "syringograde" animal, in the same category as "the *Holothuria*, and the larvæ of those insects whose progression is effected by the alternate reception and expulsion of water to and from their respiratory organs by an action similar to that of the syringe." In *Salpa* the dilatation of the test and its membranous lining causes the water necessary for respiration and nutrition to enter through the bilabiate posterior orifice, which has a valve preventing the return of the water by the same aperture †; a transverse contraction of the body then expels the water through the anterior orifice, and the result is, that the animal is forced backwards, being carried in an inverse direction to that of the ejected water. ‡ This retrograde motion has caused the posterior orifice to be regarded by some naturalists as the true oral orifice. The alternate action, of dilatation and contraction, have been observed to take place about fifteen times in a minute ; and have sometimes been termed the systole and the diastole. The contraction is effected rapidly, but the relaxation, or rather the dilatation of the sub-elastic test, takes place but slowly. These movements are synchronous throughout a chain or group of *Salpæ*.

After all, this is but an imperfect amount of locomotion, and it is extremely probable that both the single *Salpæ* and the Salpian wreaths and chains, the latter often several yards in length, are, like the feebly moving *Pyrosoma*, the sport of wind and wave, wafting them hither and thither, either to bask calmly in the sunshine, or to be broken on the rocky shore.

Affinities of the Tunicata. — Many of the early naturalists (as we have noticed in the first part of the article) noticed the analogies existing between the *Ascidia* and the *Ostrea*, *Mytilus*, and other *Mollusca*. The compound Ascidians, however, long remained grouped with *Alcyonium*, until Savigny, Lesueur, and Desmarest pointed out their alliances with the simple Ascidians and with Molluscs. Lesueur also demonstrated the ascidian character of *Pyrosoma*, and removed it from the *Radiata*, amongst which it had been grouped ; and Cuvier pointed out the alliance of *Salpa* with *Ascidia* and *Mollusca*. Soon after the publication of the important zoological conclusions thus arrived at by his distinguished countrymen, Lamarck formed these animals into a new group, under the appellation of *Tuniciers** (*Tunicata*), provisionally placing them between the *Radiata* and *Vermes*, and expressed strong doubt of their general alliance with the *Mollusca*.

John Hunter, who perceived the relations

* See art. Motion, Vol. III. p. 433.

† See figure of *Salpa cristata*, showing most of the branchial muscles and the position of the valve (the latter is ideal, not being visible externally in the animal), *fig.* 228. p. 434. Vol. III.

‡ In a communication from my friend Mr. Pittard on the subject of *Syringograde* movement, he remarks as follows: "I am not aware that a true and satisfactory explanation has ever been given of the backward motion of bodies resulting from the ejection out of them of jets or currents of fluid. That the action of such jets is at all comparable to the thrusting out of a solid body, or pole, against some resisting object, is by no means maintainable; for the property of rigidity, which is totally and in all circumstances absent in fluids, is an indispensable condition for the production of such a result. Nor is the action due to the resistance of the external medium in any other way, but solely to the hydraulic pressure of the contained fluid on the internal surface of the walls of the hollow body. It has been supposed that the resistance of the surrounding medium acts in some degree like the walls of a cannon would in the following case: — If a bomb-shell, containing gunpowder, in the act of exploding, were placed in a cannon with the match-hole of the shell open and turned towards the breech, so that an explosive jet should be projected into the cavity of the cannon, the shell would be forced out with a much greater impetus than it would have if, *cæteris paribus*, it were in the open air. But this is not a parallel case, for here you have the resistance of the closed end of the cannon in one direction, and an open end, or no resistance, in the opposite direction; whereas, in the case under consideration, you have just the same resistance from the external medium in front of the body moved, as you have behind it; and whatever tendency to motion might result from such a resistance of the medium to the jet behind, just so much would there be resisting motion in front ; so that the effect would be neutralised, and no motion would result. The truth is, that from the two absolute laws of hydraulics, — that a fluid presses equally on all portions of the surface on which it acts, and that the *direction* of this pressure or force is at right angles to such surface, — it results that the force exerted by or through a fluid contained in a closed hollow body is exactly equal in opposite directions; that is to say, whatever may be its force impelling towards the right, by just so much does it impel towards the left ; however much it impels forwards, by just so much does it impel backwards; and so on for up and down, and all other opposite directions: so that the one exactly antagonises the other, and an equilibrium results. But remove a portion of the wall ; in other words, make a hole through which the fluid may escape, and then the pressure, in the direction of the side in which the hole is made, is *minus*, or less than the force in the opposite direction, by the size of the hole. The body, therefore, moves in the direction opposite to the hole, in obedience to the *plus*, or excess of hydraulic pressure in that direction." The *Salpa*, compressing the water in its interior, produces a large amount of hydraulic force. Its posterior orifice being closed, it presents a hole or deficiency in the front only, and is impelled in the opposite direction. Also, during the act of taking in water behind, the animal moves likewise backwards, for then there is, so to speak, an inversion of the process described above. The pressure of the external water, otherwise equal on all parts of its surface, is *minus* behind by the size of the posterior orifice, and therefore *plus* in front, again impelling it backwards.

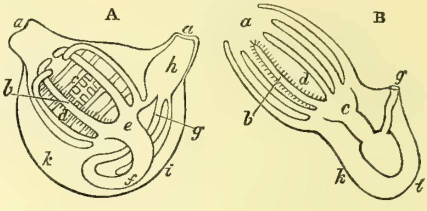
* Applied at first to the *Botryllidæ* only.

subsisting between *Ascidia* and *Salpa*, and knew the true analogy of their exterior covering, proposed to distinguish them as a distinct group of Molluscs, under the term "soft-shells," which more truly accords with their real nature than "shell-less" (*Acephales sans coquilles*), as they have been subsequently designated by Cuvier*, who also, together with Blainville, regarded them as acephalous Molluscs, and sufficiently distinct to form a separate class.

In many of the *Acephala* we find two tubes for the ingress and egress water, like those of the *Ascidiæ*, and the mantle closed throughout its length, the walls of its cavity lined with the branchiæ, and the mouth at the base of this cavity. The *Ascidia* being immovable, has neither adductor nor foot-muscles; for, being destitute of a locomotive organ and of valves, the muscles disappear, with the exception of some sphincter-like bands. Together with the muscles, the pedal nerve-ganglions, or rather subœsophageal or posterior ganglions are lost, and there remain only the buccal or supra-œsophageal ganglions. The differences between the heart and auricles of the Ascidians and the other Molluscs are dependent on the modification of the branchiæ; the latter, in Ascidians, never being arranged in the four lamellæ usually found in Molluscs. The digestive tube and the generative organs are essentially the same in *Tunicata* and *Acephala*, and in the latter, as in the former, the ovary and testicle are enclosed in the intestinal loops.

Yet however much resemblance we may find between the *Acephala* and the *Tunicata*, there is still more between the latter and the *Bryozoa*. Van Beneden observes, that if a *Bryozoon* was confined to its cell, and still to carry on its respiratory function by its unprotruded tentacles, and if anastomosing communications were established between the tentacles and a heart at their base, we should have the complete idea of an Ascidian. There would be two external orifices, a single mouth situated at the base of the branchial sac, vibratile cilia throughout the extent of the anastomosing tentacles, a folded intestinal canal, a supra-œsophageal ganglion, some muscular bands, and organs of generation developed around the digestive tube. There would be only wanting to complete the animal, a cloaca to receive the excrements, the sperm, and the ova, and a direct passage of communication between the respiratory and the cloacal cavities. The gemmiparous mode of reproduction observed in the *Clavellinæ*, and *Botryllidæ* closely resembles that which obtains in the *Bryozoa*. With regard to the development of the *Acephala*, compared with

Fig. 790.



A, *Ideal figure of an Ascidia.* (*After Van Beneden*).

a, a, the external orifices, branchial and anal; *b*, straight branchial vessels; *c*, transverse and anastomosing branchial vessels; *d*, respiratory cavity; *e*, œsophagus; *f*, digestive cavity; *g*, rectum; *h*, cloaca, communicating with branchial cavity, rectum, and generative organs; *i*, integument; *k*, peri-intestinal cavity.

B, *Ideal figure of a Bryozoon.*

a, entrance of the sheath; *b*, tentacles, hollow throughout their length, equivalent to the straight branchial vessels; *d*, the sheath; *c*, mouth, leading to the digestive cavity; *g*, anus; *i*, integuments; *k*, peri-intestinal cavity.

that of the *Tunicata* and *Bryozoa*, Van Beneden points out the following analogies: — "There exist common characters between the *Bryozoa* and the *Anodonta* in this respect; their larvæ respectively swim about by means of vibratile cilia. They have a different form in the young and the adult states, and they undergo true metamorphoses. The same phenomena are seen in the Ascidians. These also have metamorphoses, perhaps, even more complete, but instead of vibratile cilia, the embryo is provided with a caudal appendage sufficiently long to serve for the purposes of locomotion; which tail disappears, just as the vibratile cilia of the former, as soon as the animal becomes definitely fixed."

The embryogenic characters appear to entirely accord with the anatomical dispositions of these groups; and altogether we are, perhaps, justified in considering, that they approach on one side to the *Acephala*, and, through the *Pedicellina*†, they are, on the other hand, allied to the *Bryozoa*, forming a closely uniting link between these two important groups.‡

* Catal. Hunterian Museum, vol. i. p. 260. *note*.

† For Van Beneden's researches on the development of the *Pedicellina*, &c. see art. POLYPIFERA.

‡ The following tabular arrangement, given by Prof. Van Beneden in his clever exposition of the alliances of the simple Ascidians (*loc. cit.* p. 58.) is a valuable illustration of the subject.

- ANIMALS - -
  - Hypocotylédonés.
  - Epicotylédonés.
  - Allocotylédonés
    - Mollusques - -
      - Céphalopodes.
      - Gastéropodes.
      - Acéphales.
      - Tuniciers - -
        - Salpiens.
        - Pyrosomiens.
        - Ascidiens.
        - Polyascidiens.
        - Pérophoriens.
    - Polypes - - -
      - Bryozoaires.
      - Médusaires.
      - Anthozoaires.
      - Alyconaires.
  - Echinodermes.

There have been certain organic remains* figured and described as belonging to the Tunicate family, but which (with the exception of the obscure and indeterminate *Ischadites Kœnigii*) have been found to belong to the family of the *Cystidea* of Von Buch, closely allied to the crinoidean family of the *Radiata*.

At first sight there is considerable resemblance between many of these cystidean forms and the ascidian genus *Boltenia*, the body being globose or subcylindrical and pedunculated. In the *Cystidea* there are two more or less terminal orifices, and a third lateral aperture. The whole animal is coated with *hexagonal* plates variously ornamented; the stem, perforated throughout and giving evidence of *quinary* arrangement. "The mouth," says Von Buch, "is planted in the central part of the upper surface, generally in a moveable proboscis, covered with minute plates; the anal orifice is small, close to the mouth, perforating a plate, not surrounded by separate valvules; and the third aperture, probably the ovarial orifice of the animal, is placed further towards the middle, but almost invariably on the upper half of the body on which the mouth is placed. It is round or oval in form, not connected with the mouth, and often covered by a five or six-sided pyramid, which seems to be composed of as many little valves."

We have introduced this description that we may here point out the general similarity of the external form of these obsolete radiate animals to some of the ascidian group, and that we may in particular point out the very similar armature of ornamented *hexagonal* plates present in *Chelyosoma*, with its valve-surrounded orifices. With regard to the additional orifices, we have but to lengthen out the oviduct or efferent vessel of the *Ascidia*, and continue it to the surface, as in the malformation noticed and drawn by John Hunter, and a very similar arrangement of parts will apparently exist.

There are several points of analogy between some forms of *Ascidiæ* and of *Zoophyta ascidoida* (*Bowerbankia*, &c.) and the *Radiata*: into this subject we must not now enter; we can only allude to the observations of Messrs. Forbes and Goodsir on the *Pelonaia* (see p. 1239.), and leave the subject open to further investigation.

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(*T. Rupert Jones.*)

* *Leucophthalmus*, Kœnig (*Sphæronites*), *Saconites*, Rafinesque, &c.

URETHRA.—(Lat. *Urethra*; Gr. οὐρήθρα; Fr. *Urèthre.*)

In the Male.—The urethra, or uro-sexual canal, is the canal by which the urine, the secretion of the testes, of the prostate and Cowper's glands, with that of the vesiculæ seminales, are discharged. It commences at the opening in the anterior part of the neck of the bladder, and terminates at the extremity of the glans penis. In the beginning of its course it traverses the prostate gland; it then perforates the triangular ligament, which is stretched across beneath the arch of the pubis; and after passing through this it enters the groove between and beneath the corpora cavernosa penis, and is now surrounded by the corpus spongiosum urethræ; and passing through the glands, an expansion of the latter body, it ends in a slit-like orifice, the *meatus urinarius.*

Direction. — The direction of the canal varies according to the state of the penis: thus in the relaxed condition of this organ it presents curves like the italic ∽ procumbent; if we trace it backwards from the meatus, it will be seen to rise towards the pubis; thence it descends slightly, and passes beneath the arch of that bone, after which it makes a gentle curve upwards to the neck of the bladder.

When the penis is erect, the urethra is straight for at least three-fourths of its course, that is, whilst it traverses the spongy body; after which it makes a rather abrupt curve towards the opening into the bladder. In the introduction of the catheter, the surgeon, by drawing the penis forwards and upwards, straightens the anterior three-fourths of the canal, thus approximating its direction to that which it assumes in the erect state of the penis; and now, by careful manipulation, in depressing the handle of the instrument between the thighs, to a level with the urethral opening in the triangular ligament, he can, without any difficulty, succeed in passing even a straight catheter into the bladder.

It is important to remark that the anterior three-fourths of the urethra are loose and pendulous, whilst the remainder is fixed to the pubis in a manner presently to be described; a circumstance to be borne in mind in catheterisation.

The urethra is divided by anatomists into three parts, each presenting characteristic peculiarities. Thus the first part is termed the *prostatic portion*, because it is surrounded by the prostate gland; the second is denominated the *membranous portion*, because, when deprived of its surrounding structures, it is little more than a simple membrane; it is also called the muscular part, because it is encircled by muscular fibres; and the last, being entirely invested by the corpus spongiosum, is designated the *spongy portion.*

According to a rough measurement, it may be stated that the spongy portion occupies about seven parts, the membranous rather less than one part, and the prostatic rather more than one part of the entire length of the tube.

Length. — The urethra has been frequently measured to ascertain its length and diameter; and much attention has been devoted to this subject by various observers, with the view to the treatment of strictures and other diseases incidental to this canal. It need scarcely be remarked that the urethra varies at different periods of life, according to the evolution of the generative organs; and hence it is much shorter in the child than in the adult, and it is well known frequently to undergo a marked elongation in old persons, in consequence of hypertrophy of the prostate gland.

I shall here introduce the measurements in length, as given us by some practical surgeons, whose attention has been especially directed to this subject, observing that the length of the urethra is expressed by the extent to which it can be stretched, by drawing the penis somewhat forcibly forward.

According to Ducarp, it rarely exceeds nine inches in length. Whately examined the urethra in forty-eight subjects of different heights: these he arranged under three heads, viz. tall, middling, and short.

In 16 subjects of tall stature, the urethra measured

In 1 subject, 9 inches 6 lines.
8 „ 9 inches.
2 „ 8 inches.
5 „ 8 inches 6 lines.

In 23 of medium stature, it measured

In 3 subjects, 9 inches.
1 „ 8 inches 9 lines.
7 „ 8 inches 6 lines.
2 „ 8 inches 3 lines.
1 „ 7 inches 6 lines.

Whilst in 9 of short stature, it measured

In 1 subject, 8 inches 9 lines.
2 „ 8 inches 6 lines.
4 „ 8 inches.
2 „ 7 inches 9 lines.

The collective average is therefore nearly $8\frac{1}{2}$ inches, and the respective averages would stand thus: —

For those of tall stature, it would be 8in. 9l.
For those of middling stature - 8in. 2l.
For those of short stature - - 8in. 3l.

Lisfranc examined the urethra in twelve adults, and he found its length to vary from 9 to 10 inches. In a negro it measured 12 inches.

M. Petrequin has collected the various measurements of the canal, as given by the French writers on this subject, by which it appears that the estimated length varies from $5\frac{1}{2}$ inches to 12 inches. Petrequin conducted his own examinations with both straight and curved instruments. With the straight instrument he found the length of the urethra between $5\frac{3}{4}$ and $6\frac{1}{4}$ inches, whilst with a curved instrument it measured from $6\frac{1}{4}$ to 7 inches. The difference he explains by the fact, that, inasmuch as the urethra is not rectilinear, a straight instrument cannot be passed through it without effacing the angle between the bulbous and membranous portions of the canal.*

Mr. Briggs observing that most of his predecessors had examined the length of the urethra after death, made a series of examinations of the canal in the living subject; and he adopted the following mode of examination:— He introduced into the bladder a catheter without a stilet, on the stem of which was marked a graduated scale of inches and fractional parts, measured from the eye of the instrument. He observes, "as soon as the urine begins to flow from the catheter, which has only one eye, the line marked on the stem corresponding with the external meatus will necessarily indicate the exact length of the canal, or the distance from the meatus to its termination in the bladder. Of sixty persons in whom the urethra was measured thus, the length was found to vary from $6\frac{3}{4}$ to $8\frac{1}{2}$ inches. In eight instances, or rather less than one-seventh of the whole (twenty of them being persons of short stature, or not exceeding 5 feet 4 inches in height), the length of the urethra was found to be under 7 inches. In forty-five instances, or three-fourths of the number, *i. e.* in persons of middle stature, the measurement was found to be between 7 and 8 inches, and in a few it exceeded 8. In some instances of very corpulent subjects, at an advanced age, the urethra was found to be 10 inches in length." He considers the average length of the passage to be $7\frac{1}{2}$ or $7\frac{3}{4}$ inches, the external parts being in a natural condition, neither hanging in a loose, flabby state, nor unusually retracted. Briggs found the proportions of the various parts of the canal to stand relatively thus: — from the orifice to the membranous part, $6\frac{1}{2}$ inches; from thence to the bladder, $1\frac{3}{4}$ inch $= 8\frac{1}{4}$ inches. As there was no stretching of the penis in the examinations thus made, it is easy to reconcile the discrepancies between Briggs's and Whately's measurements.

Of the relative length of the different portions of the canal, M. Petrequin cites the following authorities: — The prostatic portion measures, according to Boyer, 15 or 16 lines; Littre, 15 lines; Ducamp and Blandin, from 12 to 15; Senn, 13; J. Cloquet, 15. M. Petrequin agrees with Lisfranc, that the most exact measurement is from 8 to 11 lines.

Boyer estimates the length of the membranous portion at 12 lines; Ducamp, from 9 to 12; Blandin, at 10; Lisfranc, from 7 to 11. M. Petrequin has found it to vary from 6 to 9 lines, when measured by its central axis; its upper surface measuring from 8 to 10 lines, its under surface from 4 to 5 and sometimes 6, the difference arising from the projection of the bulb beneath. The mean length of the prostatic and membranous portions taken together is, according to Malgaigne, 13 lines, but it varies from 11 to 15 lines. Petrequin has found it to vary from 14 to 18 and sometimes 20. As to the bulbous and pendulous portions of the urethra, their rectilinear measurement is 6 inches or 6 inches and 10 lines, and the curvilinear 5 inches or 5 inches and 4 lines.*

Diameter. — In diameter, also, the urethra varies according to age: thus in the young subject it is small; indeed its diameter increases in proportion to the age of the individual; and in the aged, partly in consequence of the flaccidity of the parts surrounding it, partly from the loss of contractility in its own tissue, its capacity becomes immensely increased, so that it will readily admit a catheter of half-an-inch bore, and the escape of fragments of stone of equal size.

Even in the infant, however, the urethra is more capacious than is generally imagined, and will admit a much larger sound than we should *à priori* suppose; a fact of no small importance in sounding at this early period of life. When the penis is erect, the urethra is diminished in diameter, from the pressure of the turgid veins of the spongy body, and from the increased distension of its own blood-vessels.

To ascertain the diameter of the urethra, and to compare it in persons of different ages, Sir E. Home examined the canal in two persons — one of the age of 80, and the other 30.

	At 80.	At 30.
At 9 lines from the meatus it measured - - -	5 lines	$4\frac{1}{2}$ lines.
At 4 inches 3 lines from ditto	4	4
At 6 inches from the meatus (at the bulb) - - -	7	$7\frac{1}{2}$
At 7 inches (beginning of membranous part) - -	4	$2\frac{1}{4}$
At 7 inches 9 lines (near the prostate) - - -	5	4
At 8 inches (beginning of the prostatic part) -	4	$3\frac{1}{2}$
At 8 inches 3 lines (the middle of ditto) - -	6	$5\frac{1}{2}$
At $8\frac{1}{2}$ inches (near the neck of the bladder) - -	5	$4\frac{1}{2}$

Briggs directed his attention to the diameter of the urethra in the various parts of its course, and he found the dimensions materially altered if the urethra be injected with wax or any other substance; and the result of his examination throws considerable doubt on the conclusions of Sir Everard Home. From the casts which he made he failed to discover any sudden narrowing or constriction at the termination of the membranous part of the urethra, or any resemblance in the shape of the curve as represented in Home's plates.†

Briggs remarks, "The portion of the urethra which extends from the apex of the prostate

* See the review of M. Petrequin's work (*Traité d'Anatomie Medico-chirurgique, &c.*), in the British and Foreign Medical Review, vol. xx. p. 136.

* Ibid.

† From examinations I have made myself of wax casts of the urethra, I believe the representations of Home not to be exaggerated.

forwards to a short distance beyond the arch of the pubis, and in the natural state is the narrowest part of it, when distended, greatly exceeds the rest of the canal in its dimensions, and forms a large oblong sinus from $1\frac{1}{4}$ to $1\frac{3}{4}$ of an inch in length; and in its transverse diameter at its broadest part, from $\frac{10}{20}$ths to $\frac{12}{20}$ths of an inch, the part of the urethra anterior to it not exceeding $\frac{7}{20}$ths of an inch. The broadest part of this sinus lies directly under the arch of the symphysis pubis. The narrow part of the canal, as seen in these injections, is at the point of union between the prostatic and membranous portions."

The irregularities in the form of the urethra here noticed do not appear to exist at the earlier periods of life. In a cast of the urethra of a boy 11 years old, made by injecting wax, no inequalities such as those mentioned above in the adult were observable throughout its course, the diameter of the cast, which is nearly cylindrical, measuring pretty uniformly $\frac{1}{5}$th of an inch.

Briggs found the curve of the urethra to commence $1\frac{1}{2}$ inch anterior to the bulb; and from this point to its termination in the bladder, to form an arc of a circle of $3\frac{1}{4}$ inches in diameter, the chord of the arc being $2\frac{3}{4}$ inches, or rather less than one third of the circumference. In another cast the chord of the segment was found to measure $2\frac{8}{10}$ inches of a circle of $3\frac{1}{8}$ inches in diameter, the inclination of the internal orifice, or entrance into the bladder, forming an obtuse angle with the general course of the urethra.

The same surgeon remarks, that in young subjects the posterior portion rises nearly at right angles from the rest of the canal, and consequently makes a much sharper bend; and that this ascending portion is comparatively longer than in the adult, as was observed by Camper, who justly attributes the circumstances to the higher position of the bladder in early age. A similar remark was made by Bichat; and the fact is well known to the lithotomist, who, in directing the cutting instrument into the bladder of the child, raises the point by depressing the handle at this important stage of the operation.

According to Briggs, the most depending part of the curve is at the point where the membranous portion would be intersected by a line drawn through the longitudinal axis of the symphysis pubis to the anus: this would divide the membranous part into two equal parts, and pass through the most dilated part of this portion of the canal.*

I shall now pursue the description of the canal, commencing at that part which leads immediately from the bladder, namely the prostatic portion, observing that this, together with the membranous part, is contained almost wholly within the pelvis, and the two constitute therefore the pelvic portion of the urethra, and form the true representative of the female urethra.

* Briggs, on the Treatment of Strictures of the Urethra by Mechanical Dilatation.

The *prostatic portion* traverses the prostate gland at the distance of about two lines from the anterior, four from the posterior, and seven from the lateral surface of the gland. In this respect, however, it varies considerably: thus, in some cases, it is very close to the posterior surface, especially where the isthmus of the prostate is imperfectly developed.* The prostatic portion is from 12 to 15 lines in length, and it commences at the neck of the bladder by a round opening, which is slightly raised; it then expands to the width of 4 or 5 lines, and gradually contracts itself into the membranous portion. It varies in length and direction in different subjects, and differs materially in these respects according to age. Lisfranc examined it in eight healthy subjects, and found the diameter of the anterior and posterior portions to vary from 3 to 4 lines, whilst the middle portion measured from 4 to $5\frac{1}{2}$ lines.

Although closely invested by the dense tissue of the prostate and its capsule, this is nevertheless the most dilatable part of the whole urethra, and will readily admit the introduction of the fore-finger. The *levatores prostatæ* muscles, together with the *pubo-prostatic* ligaments, support it, and attach it to the pubis, and it is compressed by the *levatores ani*. The general direction of this division of the canal is obliquely downwards; it presents a slight concavity (*the prostatic sinus*) at its floor, where it is traversed by the *caput gallinaginis*, which, running from behind forwards, divides the sinus into two equal parts. In the prostatic sinus the ducts of the prostate open, assuming a crescentic arrangement around the base of the caput gallinaginis, whilst the vasa ejaculatoria terminate usually on the side of the latter body.

The description of the urethral orifice of the bladder belongs to the anatomy of this viscus, and to the article Bladder the reader is referred; but it is requisite here slightly to allude to it, as it bears materially upon the general direction of this part of the urethra. When viewed from before backwards, the opening will be generally found somewhat raised, so that the floor of the urethra forms a slight depression; and this depression is materially increased in hypertrophy of the prostate, a circumstance always to be remembered in the introduction of the catheter in such cases.

In infancy the direction of the prostatic part is very different from what it is in after life. In consequence of the bladder at this early period being situated higher up, that is, more in the abdomen, the urethra at this part rises more vertically, and thus forms an angle with the membranous portion; hence, as in the aged, the necessity, in passing a sound or catheter, to depress the handle to a considerable extent, and thus to raise the point of the instrument. As the prostate becomes evolved,

* Lisfranc mentions an instance where the isthmus was wholly wanting, and the urethra formed a remarkable pouch at this part.

the prostatic part of the urethra gradually descends, until its general direction is more continuous with that of the membranous part. I shall defer the description of the caput gallinaginis until I come to that of the general surface of the urethra.

The connection of the urethra to the prostate is very close, the ducts of the gland passing directly into it; it is therefore impossible to raise it from its attachment without division of the prostatic ducts. When a catheter is introduced, the course of the canal invested by the prostate can be indistinctly traced by the finger introduced into the rectum.

The *membranous portion* (*pars muscularis, isthmus urethræ*) commences from the anterior part of the prostate, and extends beneath the arch of the pubis as far as the bulb: it is included between the prostatic and spongy portions, and is covered slightly at its anterior and under part by the bulb, so that it is really shorter below than above. It makes a slight curve, the concavity facing upwards. The concavity is at the distance of nearly an inch from the interpubic substance; the convexity looks towards the perinæum. Between it and the pubis, and just beneath the pubic arch, the dorsal veins of the penis run.

Proceeding from the anterior extremity of the prostate, the membranous portion of the urethra traverses the *triangular ligament*, which splits into two lamellæ: one passing backwards over the prostate, is continuous with the capsule of the gland, the other advances forwards over the bulb, and blends with the tendinous investment of the spongy body. The opening through which the urethra passes is round. The membranous portion forms the segment of a circle, whose radius is, according to Krause, $2\frac{1}{2}$ lines. This part of the canal has been termed membranous, from the idea that it represented a simple membrane when deprived of its surrounding muscular structure, and that it was wholly destitute of any investment of the spongy body. This, however, is not correct; there is a thin layer of vascular tissue, continuous in front with the spongy body, and closely surrounding the mucous membrane of this part of the urethra, between it and its muscular layers. The vessels of this extension of the spongy body pass backwards, to terminate in the plexus surrounding the neck of the bladder: this is mixed up with elastic tissue, and constitutes a truly erectile tissue. An extension of the same structure enters into the formation of the caput gallinaginis.

Between the layers of the triangular ligament, and in close connection with the membranous part of the urethra, are found three sets of muscular fibres (*musculus urethralis*): they consist of the two pairs of muscles described, one by Wilson and the other by Guthrie; and the circular fibres of Santorini, which closely surround the urethra. The anteprostate, or Cowper's glands, covered by the inferior stratum of the compressor urethræ, are placed beneath this part, and the arteries of the bulb are in close approximation to it, running beneath and on either side of it. The floor of the membranous portion is traversed longitudinally in the median line by the pointed end of the caput gallinaginis.

If a catheter be passed into the bladder, the membranous portion can be distinguished by the finger introduced into the rectum and drawn forwards, there being only a small quantity of cellular membrane interposed between the under part of its muscular investment and the intestine.

Boyer estimated the length of the membranous portion at about 1 inch; Ducamp from 9 to 10 lines; Lisfranc found it in twelve subjects to vary from 7 to 11 lines. In these its anterior diameter varied from $3\frac{1}{2}$ to $4\frac{1}{2}$ lines, its posterior from $4\frac{1}{2}$ to 5 lines, and just behind the bulb it measured at least $1\frac{1}{2}$ line less than in any other part. It is universally admitted that the point of junction between the membranous and spongy portions is the narrowest part of the urethra, with the exception of the meatus.

The membranous part of the urethra is surrounded by muscular fibres, which have been variously described by different anatomical writers. Thus Santorini, as early as 1724, in his *Observationes Anatomicæ*, pointed out some transverse fibres as encircling the urethra at this part: he terms them "the elevator or ejaculator urethræ," and describes them as being inserted into the lower part of the urethra. Mr. Wilson, in the year 1808, gave a description of two muscles surrounding the membranous part of the urethra, the origin of which is from a tendon attached to the posterior part of the symphysis pubis, a little above its lower border: the muscle thus arising from a single origin then descends, and divides into two portions, which, reaching the membranous portion of the urethra, spread themselves out by its side, and are implanted into a common tendon below it. The muscle is termed by Wilson the compressor urethræ. In 1834, Mr. Guthrie, in his lectures at the Royal College of Surgeons, demonstrated another series of muscular fibres, as surrounding the membranous portion of the urethra, and of which he considers Wilson's muscle as a part. That portion described by Guthrie, and now known by his name, arises by a thin tendon on either side, from the ramus of the ischium, and, passing transversely, splits into two portions, one above and the other below the urethra; the two muscles are connected together above by a mesial tendon, which, passing forwards, is inserted in part into the upper part of the urethra, whilst another portion, passing backwards, is implanted into the upper surface of the front of the prostate. The under portion of the muscle is also connected with its fellow by a similar mesian tendon, which, advancing forwards, goes to the central tendon of the perinæum, and, sending a slip backwards, is inserted into the under part of the prostate.

The muscles are included between the two layers of the triangular ligament; and the effect of this muscular apparatus must be to support and compress this part of the urethra, and to prevent any retrogression of the seminal fluid in the venereal act.

The urethra now enters the *corpus spongiosum*, by which it is surrounded, until its termination at the extremity of the glans penis. The spongy body surrounds the urethra equally, except at the bulb and at the glands: in the former situation there is a much thicker layer below than above, which gives to the bulb an appearance of great dilatation, whilst at the glans there is but very little of this structure at the under part. The bulb and the glans, both dilatations of the spongy body, bear a tolerably constant relation to each other.

This part of the canal is called the *spongy portion:* it has already been stated that its length varies in different subjects, and according to the condition of the penis, being 4 or 5 inches in the flaccid state, and 6 or 8 inches in the erect condition of the organ. It commences at the termination of the membranous portion, and is lodged in a groove between and beneath the corpora cavernosa penis, forming, with its investing corpus spongiosum, a convexity, projecting beyond the general circumference of the penis.

The direction of the spongy portion is curved; it passes upwards in front of the lower part of the symphysis pubis as high as the suspended part of the penis; and then taking the direction of this organ, it bends downwards, thus forming an abrupt curve: by simple traction of the penis forwards and upwards, it can be rendered perfectly straight.

If the spongy part of the canal be laid open longitudinally, it is found to be plicated, the folds running from behind forwards, and dovetailing with one another when the urethra is closed. This plicated arrangement of the mucous membrane of the spongy portion was observed by Bichât and others, and is due to the contraction of the submucous tissue: if the urethra be immersed in alcohol and examined with the aid of a simple lens, an arborescent arrangement of the folds is visible at the anterior part of the canal, in appearance not unlike the plicæ in the mucous membrane of the cervix uteri.

The spongy portion varies in diameter in different parts; thus, dilated at its commencement in the bulb, it gradually tapers until it reaches the glans, when it suddenly expands into the fossa navicularis, to be again contracted at the meatus.

The *bulb* (*pars bulbosa urethræ et pars subpubica*) is the widest part of the spongy portion. Lisfranc found in twelve subjects it varied in diameter from 5 to 7 lines. Home and most anatomists who have examined the urethra, have come to the general conclusion that the bulbous portion presents a decided dilatation, and a simple examination of the part would lead to a similar conclusion. I cannot, therefore, conceive why there should be any doubt on the subject. Injections of wax prove to my mind an undoubted dilatation of the bulbous part; Krause and Guthrie, however, deny that any such exists.

Kobelt has shown, that if the bulb be injected, the corpus spongiosum at this part presents two lateral hemispherical swellings, separated from each other in the middle line by a longitudinal depression. "This is caused by a septum which divides the posterior part of the bulb into two lateral symmetrical halves; but anteriorly it is gradually lost. The two portions of which it indicates that the bulb is composed, are the analogues of the completely divided portions of the bulb and corpus spongiosum in the whole of the marsupial tribe."* "In the middle of the bulb there is a slight superficial elevation (*colliculus bulbi medius*), which is situated above and between them, but does not extend so far backwards as they do, and gives passage to the membranous part of the urethra, the vessels and nerves of the bulb, and the ducts of Cowper's glands."†

The extremity of the caput gallinaginis sometimes reaches the bulbous portion, and the ducts of Cowper's glands terminate in its floor by two minute orifices, extremely difficult to find. This part of the canal extends for about the fourth part of an inch or less, the anterior layer of the deep perinæal fascia covers it underneath, and it is completely invested by the acceleratores urinæ.

The remainder of the spongy portion is united to the bulbous at an angle of 45 in the flaccid state of the penis; but when this organ is erect, this part of the canal is rendered perfectly straight: it terminates at the meatus urinarius.

The extremity of the spongy portion is called the glandular part (*pars glandularis*), being surrounded by the glans penis. When the urethra has entered the glands, it dilates into a fossa from 4 to 6 lines in length, this is termed the *fossa navicularis Morgagnii.* When cut transversely, it has the appearance of a longitudinal fissure. The urethra is surrounded unequally by the glans penis; the floor of the navicular fossa is covered by a very thin layer of this extension of the spongy body, whilst its sides and upper surface have a considerable investment from the glans.

The urethra having traversed the corpus spongiosum and the glands, terminates at the anterior and inferior part of this body, by a small slit-like orifice of two or three lines, the long axis of which is vertical: from this a small fold of membrane passes down to join the prepuce, and is termed the *frænum præputii.* The effect of this latter is, when the penis is erect, to draw down the opening of the urethra, and thus to narrow the orifice, and direct the contents of the urethra downwards and forwards. The two sides of the meatus urinarius are kept in apposition by the projection of the glans, and they are joined below by a delicate fold of mucous

* British and Foreign Quarterly Review, vol. xix. p. 508.

† Ibid.

membrane, not unlike the fourchette of the female labia.

The urethral orifice is surrounded, according to Guthrie*, by a peculiar dense structure, which he considers analogous to that which forms the edge of the eyelid, and which he believes to be requisite to maintain the patency of the opening; for if this be destroyed by ulceration, the part from which it has been removed contracts, and the opening becomes so small, as to give rise to a most troublesome form of stricture. The opening of the urethra is almost invariably the narrowest part of the canal; and hence, if an instrument has been introduced through this, it will with facility traverse the remainder of the passage, unless there be some mechanical impediment from spasm or disease; and hence a trifling division of this part will permit the passage of a large instrument, and the escape of fragments of stone, which are frequently arrested here after the operation of lithotrity. It is but sparingly elastic. After immersion in alcohol, the mucous membrane at the meatus urinarius will be found arranged in circular folds.

In briefly reviewing the condition of the urethra as connected with the structures investing it, we observe that the prostatic portion, being surrounded by a body possessing considerably dilatability, remains under almost every condition passive and yielding; and hence it happens that a catheter, having reached this part of the canal, must, if its point be properly directed, enter the bladder, unless there be some enlargement of the prostate itself; and hence the inference that no force is to be employed in passing the catheter under these circumstances.

On the contrary, the membranous portion of the urethra is a part of high irritability. This depends partly on the nature of the tissue itself, but mainly on the muscular apparatus connected with it. This part of the canal is most liable to irritation and spasm from general and local causes; and is well known to be the most frequent seat of stricture. The remainder of the urethra is entirely surrounded by the corpus spongiosum, and must necessarily be influenced by the condition of that body. When the latter is distended, as in erection, the diameter of the urethra must be proportionally diminished; and, in the undistended state of the former, it assumes its greatest degree of dilatability. Consequently, in the introduction of the catheter, the chief difficulty, even independent of organic disease, is experienced at the meatus, or at the angle formed at the junction of the bulb and anterior part of the spongy portion, or at the membranous part, the remainder of the spongy portion in the healthy state seldom offering any resistance to the progress of the instrument.

It will also be further remarked, that the dorsal surface of the urethra is smooth and even throughout, except in the situation of the lacuna magna, whilst its depressions and elevations are found upon the floor of the canal, and hence the importance in catheterisation of keeping the beak of the instrument against the superior part of the urethra.

Mucous Membrane. — The urethra is essentially a mucous canal, forming an important part of the genito-urinary mucous system. It is continuous with the mucous membrane of the bladder, and blends at the meatus with the cutaneous covering of the glans penis. There is always a distinct line of demarcation at this part, the urethral surface being moistened by a mucous secretion. When laid open, it can be frequently seen to present two distinct white lines, one at the upper, and the other at the under surface, running longitudinally; these are supposed to indicate the original lateral division of the canal. Independent of this, the mucous membrane will be generally found arranged in longitudinal folds, with furrows between them. The folds vary in depth and breadth, the larger are found on the under surface, and they are more numerous in this situation than above. They commence at the bulb and run forwards, sometimes continuing of the same size throughout, frequently tapering and sending off, as they approach the extremity of the penis, delicate processes, which present a somewhat arborescent arrangement, not unlike that presented by the lining membrane of the uterus; many on the dorsal aspect will be seen to terminate on either side of the lacuna magna. The folds of the urethra, which are not always visible after death, result from the contraction of the submucous layer, and are so arranged, that, when the two surfaces are in apposition, especially if the vessels of the urethra be injected, a sort of dovetailing of the mucous membrane occurs, bearing a slight resemblance to the plicated arrangement of the œsophagus of the whale.

The urethra after death is whitish in colour, and in some parts so transparent as to permit the veins of the corpus spongiosum to be seen through it. Its bloodvessels are readily injected, when the whole canal presents a beautiful vermilion tint. At the membranous portion, Shaw has described a considerable plexus of veins beneath the mucous membrane of the urethra: these veins are spread all over the canal, but are accumulated at the membranous part, lying one over the other in its long axis, so as to form two distinct columns with a groove between them: they unite and surround the sinus pocularis. Wilson had observed this arrangement of vessels, before Shaw published his description of them. These veins communicate with the plexus surrounding the prostate and neck of the bladder. They are best seen by inserting a tube beneath the mucous membrane, and injecting them with mercury. Shaw supposes them capable of considerable distension, and thus of producing a species of erection of this part of the tube.* In rude attempts to pass a catheter, the vessels of this part are often

* Lectures on Diseases of the Bladder and Urethra.

* Medico-chirurg. Trans. vol. x.

lacerated, and pour out a large quantity of blood. They have no communication with the veins of the corpus spongiosum itself, properly so called.

The colour of the mucous membrane depends on the degreee of vascularity in different parts. Thus, at the meatus, it is of a pink aspect, becoming gradually pale towards the bladder. But in the membranous portion, owing to congestion in the veins, it is very frequently much darker, as these vessels are readily distinguishable through the membrane, whilst in the prostatic part it is white. The colour of the mucous membrane is much heightened under inflammation: this is especially visible in the fossa navicularis, and at the orifice in severe attacks of gonorrhœa; and the same has been witnessed in other parts of the canal after division of the urethra, during an attack of gonorrhœa. Under inflammation it loses its smooth, polished aspect, and presents a velvety appearance.

Mr. Quekett has lately made some beautiful injections of the vessels of the mucous membrane of the urethra, in which it is seen that, in the bulbous portion, the bloodvessels running in the valleculæ between the columns are larger and more numerous than those of the columns themselves; whilst nearer the meatus, where the columns are either small or altogether absent, the membrane is not unfrequently provided with villi, which resemble those of the lips and extremities of the fingers and toes in having each a single looped capillary.

Lacunæ. — The whole of the urethra, except the prostatic portion, is marked by minute openings, distinctly perceptible at the upper and under surface, but they are certainly larger and more numerous on the upper. They are the openings of the *lacunæ* or mucous glands, whose office it is to secrete a bland fluid for the lubrication of the canal, and thus to facilitate the onward progress of the contents of the urethra. The lacunæ vary in different individuals in size and number: some anatomists believe them to be more numerous in the membranous portion: my own observations would lead me to the conclusion, that the greater number are to be found in the spongy portion. They are termed indiscriminately the glands of Littre and Morgagni, or the orifices are called the lacunæ of Morgagni, whilst the crypts opening into them are termed glands of Littre. The lacunæ vary in depth: in some situations they admit the passage of bristles, to the depth of two or three lines; in others they are by no means so deep, whilst in other cases they are scarcely perceptible. Their orifices face for the most part obliquely forwards towards the meatus, but now and then they pass vertically to the surface; they are found between and upon the columns of the urethra. A simple examination of the lacunæ would represent them as mere inflexions of the mucous membrane of the urethra, and many of the smaller ones are of this nature: some, however, present a cellular appearance, but this seems to arise from the anastomosis of vessels distributed on them: they are lined with epithelium of a character similar to that lining the urethral membrane generally, and a considerable plexus of vessels is distributed around them. Under inflammation they pour out a copious secretion, and are not unfrequently the seat of special disease. The use of the lacunæ is to extend the secreting surface of the mucous membrane of the urethra, in situations where any glandular apparatus would have been obviously inconvenient.

In old cases of stricture, and other diseases of the canal, they become exceedingly enlarged.

The lacuna magna. — Near the termination of the urethra, and within a few lines of the meatus urinarius, will be seen an inflexion of the urethral membrane, forming a *cul-de-sac*, into which the blunt end of a probe can be passed: this is denominated the *lacuna magna*, being in structure and function analogous to the other lacunæ of the urethra. The lacuna magna is a point in the anatomy of the urethra of some practical import, inasmuch as it is likely to arrest the entrance of a catheter, and to convey to the ignorant an erroneous idea of stricture. It varies in situation in different individuals. It is usually placed at about one-third of an inch from the meatus on the dorsal aspect of the fossa navicularis, so that, on separating the lips of the meatus, it can be brought into view; but it is occasionally further back, and now and then is placed on the under surface, and in many cases I have in vain tried to find it. I believe it is occasionally altogether absent. It will be found, where the columns of the urethra are developed, that they take their course towards the lacuna, and, on reaching it, pass off in slender processes to the meatus. In an urethra which I recently examined, I found a *lacuna magna* of considerable size in the under surface of the urethra, behind the middle of the spongy body. Into this the point of a catheter could be readily passed, and it might have been easily mistaken for stricture.

Hunter, and most of his successors, believe the matter of gonorrhœa to be incubated in the lacuna magna.

Structure. — The urethral membrane is divisible into two distinct layers. The inner, which is analogous to other mucous surfaces, consists of a basement membrane covered throughout by epithelium. This, according to Quain and Sharpey, for the most part, is of the scaly character, but in the vicinity of the bladder it is spheroidal. Henle describes the fossa navicularis as covered with small flat and roundish scales, whilst the remaining part of the urethra is covered with a single series of prismatic particles.*

Beneath the mucous membrane there is a layer composed of a tissue or structure of a mixed character, containing some contractile fibres, supposed to be muscular, blended with elastic tissue. It is connected to the delicate tendinous covering of the corpus spongiosum, and is supported by transverse tendinous bands distinctly visible beneath it. This layer

* See article Mucous Membrane.

varies in depth in different parts, and is thicker in the membranous than in other parts of the urethra. When examined with the microscope, it presents abundant evidence of the existence of contractile fibre mixed with common elastic tissue. The relative quantity of these elements varies according to situation: thus, in the membranous portion, there is less of the contractile tissue than in the spongy portion; a circumstance of some interest, as, this part being surrounded by a distinct muscular covering, there would be less necessity for it than in other situations where muscle is absent. The bloodvessels from the spongy body shoot through it. This contractile tissue is identical with that recently described by Kölliker as entering into the structure of the spleen and mucous canals, which have an evidently contractile power.

The existence of this layer has been long recognised, and the attention of anatomists was directed specially to it by Sir E. Home, who believed it to be muscular; and his opinion was supported by the observations of Mr. Wilson, who attributes the resistance occasionally, in irritable states of the urethra, offered to the introduction of the catheter, and the expulsion of bougies in like conditions, to spasm of these supposed muscular fibres. This idea, however, was opposed by Sir Charles Bell; but the dispute is deprived of its interest since the discovery by Kölliker of the true nature of this peculiar tissue, which combines to a certain extent the attributes of organic muscular fibre and elastic tissue. This layer varies in depth in different subjects, and is generally highly developed in the robust and muscular, so as in some individuals to grasp with considerable firmness a bougie when introduced into the canal. Wilson mentions an instance of a gentleman who could "as distinctly feel a contraction of the passage coming on, and taking place at one part, as he could feel any muscle act." The use of this layer must necessarily be to regulate the force of the current of fluids through the urethra.

According to Kölliker the following is the arrangement of the submucous layer in various parts of the urethra. It is termed by him the simple muscular tissue. "Its relations are most complicated in the prostate gland, and the prostatic portion of the urethra, which is rich in muscular fibres. So large is the quantity of this tissue in the gland itself, that the true glandular structure constitutes scarcely one third or one fourth of the whole. On removing the mucous membrane from the prostatic portion of the urethra, the yellow longitudinal fibres of the caput gallinaginis come first into view, which form the lower end of the trigone, and contain very few muscular fibres. On both sides of the caput gallinaginis, and extending to the anterior wall of the urethra, similar yellowish longitudinal fibres present themselves, and form a strong layer towards the neck of the bladder; but towards the membranous part of the urethra they gradually decrease to a very delicate layer. This *longitudinal* fibrous layer of the prostatic part is connected, internally to the sphincter vesicæ, by a thin and indistinct layer of fibres with some of the longitudinal muscular fibres of the bladder; but by far the greater part of it is unconnected with this latter: it consists of half fibro-cellular tissue with many nucleus-fibres, and half of evident, smooth, muscular fibres with characteristic nuclei. After this, and external to it, follows, secondly a strong layer of yellowish circular, fibres of muscular and elastic tissue. This layer is connected above with the sphincter vesicæ, where also it is most developed; whilst below it becomes gradually thinner, and below the caput gallinaginis is either lost, or appears only in very small quantities. On removing the several muscular layers, we come at last to the proper glandular tissue of the prostate, of which individual lobes penetrate among the circular fibres just mentioned, their excretory ducts passing through the longitudinal fibres.

In the membranous part of the urethra the smooth muscular tissue is less developed. Under the mucous membrane, whose cellular tissue is remarkable for abundance of elastic fibres, there is a layer of longitudinal fibres, which are connected with those of the prostatic portion. These fibres consist for the most part of fibro-cellular tissue with nucleus-fibres, and include, in small numbers, undulating, delicate, and curved contracting fibre-cells (of the nature of smooth muscular fibres), which may be, in part, isolated; and are from 0·07 to 0·1 of a line long, from 1·002 to 0·003 wide. They contain small nuclei from 0·012 to 0·014 long, and are more easily found in recent specimens than in those treated with acetic acid. External to these longitudinal fibres there is a strong layer of transverse fibres, which belong for the most part to the *musculus urethralis*. Some of these, however, especially those belonging to the inner layer, display some strong bundles of smooth muscular fibres, together with fibro-cellular tissue and nucleus-fibres, and a partial mixture of fasciculi of the transversely striated fibres of the *musculus urethralis*.

The smooth muscular fibres are generally still less developed in the spongy portion of the urethra. In some cases they appear in exactly the same manner as the longitudinal fibres in the membranous portion; in other cases, longitudinal fibres may be seen, but no muscular tissue can be found mingled with the cellular tissue and nucleus-fibres of which they consist. At a certain depth, however some longitudinal fibres are distinguishable, with a more or less considerable admixture of smooth muscle, which fibres cannot be regarded as beams of the corpus cavernosum urethræ (*corpus spongiosum*), since they have no venous spaces between them, but rather form a continuous membrane, which limits the corpus cavernosum urethræ towards the mucous membrane. One might consider this part as belonging to the corpus cavernosum urethræ; in which point of view we shall deny any muscular membrane to this region of the urethra: but it seems more natural to regard the whole corpus *cavernosum* as a highly developed muscular layer provided with peculiar bloodvessels; for a large quantity of smooth muscular fibres, together with the cellular tissue, vessels, and nerves, entering into the structure of its beams and cords as far as the glans, render this body an eminently contractile structure."*

On laying open the urethra from its origin at the neck of the badder, the first structure we meet with is the *caput gallinaginis* (*colliculus seminalis, caruncula seminalis, veru montanum, crista urethræ*). This is an elongated body situated on the floor of the prostatic part of the urethra: it varies in length from three quarters of an inch to an inch. Commencing by a gentle elevation of the urethra, towards which, on either side, are seen some delicate folds of membrane passing, it expands into a small oblong rounded eminence, compared to the head of a woodcock, and hence its name: it then advances gradually, tapering to a slender point, which, being continued onwards for some distance, is lost at the beginning of the membranous portion in one or two delicate longitudinal folds, and is confounded with the general surface of the urethra: the latter part is compared to the beak of the bird. The caput gallinaginis divides the prostatic sinus into two lateral depressions, into which the secretion of the prostate gland is poured.

At the most elevated portion of the caput gallinaginis there is a depression formed by an inflexion of mucous membrane, facing forwards, variable in size and depth, and generally capable of admitting the blunt end of an ordinary probe: in some cases it can be traced down beneath the third lobe of the prostate, to the extent of the third, or even the half, of an inch. It is called the *sinus pocularis, utriculus prostaticus*, or *vesica prostatica*, and is the homologue of the *protometra*, from which the female uterus is evolved.† On either side of this, between its laminæ, or beneath it, are the terminations of the ejaculatory ducts. A general description of this small cavity has been given under the head of Prostate Gland.

The structure of the caput gallinaginis is this: it is for the most part formed of a raised fold of the ordinary mucous membrane of the urethra, beneath which is a longitudinal layer of elastic tissue continuous with the trigone. Some anatomists also affirm that there is mixed up in the tissue of the body a plexus of vessels, constituting a distinct erectile tissue; and hence it has been imagined, that when its vessels are distended with blood, as during erection of the penis, it shuts up the prostatic portion of the urethra, and thus prevents the passage of the semen in a retrograde direction into the bladder. My own opinion as to its use is, that, independent of this office, it is endowed with special sensibility, like the papillary orifices of the ducts of Steno and Wharton; and that it is capable, under the influence of a stimulus, of becoming erect, and thus straightening the termination of the canals connected with it, by which the exit of the secretion of the testes and vesiculæ seminales is favoured. I believe, further, that something more is due to these papillary orifices of the ducts of glands, and that, in consequence of their exquisite sensibility and sympathy with the glands, they possess a power, under stimulation, of eliciting the secretion and expulsion of the fluid of the bodies with which they are connected. A proof of its sensibility may be deduced from the fact, that when a bougie, introduced for the first time *per urethram*, reaches this point of the canal, it frequently gives rise to faintness and sickness; and this is usually attended with an almost irresistible desire to micturate; and further, that if this be frequently repeated, and the caput gallinaginis be irritated, a flow of semen and vesicular secretion can be excited.

The pathology of this portion of the canal leads to the same conclusion. For the relief of nocturnal emissions, so frequently the result of repeated self-pollution, the præternatural irritability of this part may be successfully destroyed by the application of the nitrate of silver.

If the caput gallinaginis be gently raised by dissection from the subjacent tissue, it will be found lying on a delicate tendinous layer, with which it is intimately connected. This layer in shape resembles the body itself, being broader behind and tapering in front, and is gradually confounded with the tendinous covering of the spongy body: it is also continuous with the fascial layer of the utriculus prostaticus.

The caput gallinaginis results in a great measure from the coalition of the two lateral portions of the urethra, during the development of the back part of the canal, from that portion of the uro-genital sinus which gives origin to the prostate and vesiculæ seminales, &c.

In the membranous portion there is nothing specially remarkable, except that delicate venous plexus, to which allusion has been already made. In the bulbous part are the terminations of the ducts of Cowper's glands; and to these bodies I shall now direct attention.

Cowper's glands — (*glandulæ Cowperi, gladnulæ antiprostaticæ vel prostaticæ inferiores*) are two glands situated beneath the anterior portion of the membranous part of the urethra, just behind the bulb, between the layers of the triangular ligament. A few fibres of the compressor urethræ pass beneath them. Sometimes a single gland only is found, and occasionally there are three; in which case, according to Cowper, the additional gland is placed just beneath the pubis. These bodies are frequently difficult to find, and in old persons they either disappear altogether, or become so soft that it is impossible to recog-

* Kölliker, Beiträge zur Kenntniss der glatten Muskeln, in the Zeitschrift für Wissen.

† See article Prostate.

nise them. In their natural condition they are rounded, or nearly so, and equal in size to an ordinary pea. Solid and resisting to the feel, they are of a palish red colour, and distinctly conglomerated, or composed of small lobules. The lobules of the glands are connected together by cellular membrane, and by their efferent ducts. The glands are surrounded by a strong capsule of fibrous membrane. On section they present an appearance like the pancreas, and are composed internally of elongated cellular follicles, which, according to Krause, vary from the 50th to the 25th of a line in length, and are about the 36th of a line in breadth. Some of these follicles equal in size a 16th or 25th of a line. They unite into slender ducts of about the 18th or 16th of a line in diameter; these usually coalesce into a single excretory duct. The excretory duct of each gland is occasionally double: the ducts run parallel for the distance of half an inch beneath the mucous membrane of the bulb, and approaching each other, they pierce the urethra by two exceedingly minute orifices, which are scarcely distinguishable: the best mode of demonstrating the openings of the ducts is gently to press the mucous membrane forwards with the handle of a scalpel, when a small quantity of secretion contained in them will escape, and indicate their termination on the mucous membrane.

Each gland receives a branch from the *artery* of the bulb, and its *veins* terminate in the pudic vein.

It is impossible to collect any quantity of the secretion of Cowper's glands sufficient for chemical analysis. According to Krause, the fluid is somewhat similar to that secreted by the prostate; it is of a viscid character, transparent, containing flocculi and small granulations, probably the detritus of epithelial cells, varying in size from the 900th to the 370th of a line, the greater number being about the 455th of a line.

Comparative anatomy. — As there is so little of a satisfactory nature known about the use of Cowper's glands in man, it may not be uninteresting to examine their condition in the animal kingdom generally. To elucidate this part of the subject, I select the following observations from the Leçons d'Anatomie Comparée of Cuvier.

According to Cuvier, Cowper's glands exist in all the *Quadrumana* and *Cheiroptera*, and amongst the *Feræ* they are found in the *ichneumon*, in the *civet*, *hyena*, *cats*; in the *Rodentia*, except the hare; also in the *Pachydermata*, most of the *Ruminants*, and all the *Marsupiata*, They are absent in the *Insectivora*, the *bears*, the *racoon*, *otter*, and *marten*, and in the *dog*. Amongst the *Ruminants*, they are wanting in the *deer;* they are absent in the *Solipeds*, *Phoci*, the amphibious *Quadriremes*, and the *Cetacea*. It will be found that they often co-exist with the prostate and vesiculæ seminales, or with these and the vesiculæ accessoriæ, or with the prostate alone.

In the flesh-eating *opossum*, they are the only accessory glands, and they appear essential to this division of the *Marsupiata*.

In *structure* they vary considerably, but may all be arranged under one or two heads. Thus like the prostate, in some animals, there is a large reservoir in the centre of each gland, from which the excretory duct arises; whilst in others the gland is composed of a number of minute follicles, all terminating in one common excretory duct.

In the *squirrels* and *marmots* they are large and vesicular, and were mistaken for vesiculæ seminales. The fluid which they contain is semi-transparent, or of a bluish, opaline appearance, of the consistence of starch, and it is poured into the bulbous portion of the urethra by a single orifice. They are completely surrounded by a muscular or musculo-membranous envelope.

In the *ape* tribe they are proportionally much larger than in man. In the *mantis* they are remarkable in size. Their excretory ducts run close together prior to their termination.

In the *bat*, amongst the *Cheiroptera*, they are very large.

In the *dismar* of Russia they are elongated, and bent in the form of the knee.

In the *hedgehog* they are broad and round composed of a number of straight, short tubes, lying parallel, and dividing into a number of exceedingly small ramuscules. The tubes unite into a single canal, which opens into the pelvic portion of the urethra.

In the *civet* and *cat* they are large, and enveloped in a thick muscular layer; but, amongst the *Carnivora*, they are largest in the *hyæna;* the lobes and branches of their secreting tubes are exceedingly distinct and large.

The anti-prostate glands of the *ichneumon* form a remarkable swelling at the commencement of the bulb; they are rounded, and composed of vesicules communicating together; these unite into a single canal in each gland, which passes beneath the penis, and opens separately into a *cul-de-sac*, into which the urethra opens. They are surrounded by an aponeurotic and muscular layer.

There is a similar structure in the *marmot;* they are shaped like a club, the broad end folded upwards against the handle, which contains the duct; the mass is divided into a number of glandular cells. The excretory duct opens into a *cul-de-sac*, hollowed out in the bulb: this contracts into a narrow canal, which opens into the urethra, near the middle of the penis.

In the *rat* they are of large size, whitish externally, and pyriform in shape. In the *agouti* they are broad, rounded, and very vascular.

In the *guinea-pig* they are more rounded, but of the same structure.

They are spherical, and situated behind the acceleratores arising in the *gerboa de Mauritanie*, and pyramidal in the *gerboa de Schaw*. They are broad and rounded in the *elephant;* they have a similar structure as the prostate, but are comparatively larger; they are reddish in colour, very irregular externally, and present a lobular appearance. They are divided into two portions; a smaller, near the bulb, and another large portion. In the centre of the first there is a considerable cavity, which receives the fluid poured into it by smaller cavities, and these communicate with still smaller cellules. From the principal cavity a canal arises, which, communicating with that of the other portion of the gland, forms a single common canal. The excretory duct is formed of two branches; it passes a short distance in the walls of the urethra, before it opens into the bulb. The glands are covered by a thick muscular layer, the fibres of which converge to a tendon, which is fixed to each corpus cavernosum.

In the *wild boar* the gland is elongated and cylindrical, formed of a firm substance composed of minute cells, which uniting form larger cells, and these communicate with a common central cavity, from which an excretory duct arises; this opens on the side of a cul-de-sac in the commencement of the bulb of the urethra. They are each completely surrounded by a muscle. In *Solipeds* they form an oval swelling on each side of the pelvic portion of the urethra. They are surrounded by muscular and tendinous fibres: each opens by a dozen orifices, ranged in rows, into the adjacent part of the urethra.

Amongst the *Ruminants*, in the *chamois*, they are of the shape and size of a pigeon's egg; its canal terminates in the usual situation. They are similar in all ruminants where they exist.

Amongst the *Marsupialia* they are remarkable for their number: thus, there are as many as six in the *Mexican opossum*, *phalangers*, *phascolymus*, and *giant kangaroo;* four in the *sarigue* and *kangaroo-rat*. In the giant kangaroo two are placed, one by the side of the other, over the urethra, just behind the crura penis; two others are situated on each side behind the crura, and are larger than the others. They are all invested by a muscular and aponeurotic envelope, and are composed of canals passing lengthways: they resemble in structure the prostate.

In the *echidna* and *ornithorynchus*, amongst the *Monotremata*, there is a gland on each side of the cloaca, small, and of an oval shape, containing within it a central canal opening into an excretory duct: this penetrates the constrictor cloacæ, and joins a small seminal canal detached from the urethra, near its termination in the cloaca. The gland is surrounded by a thick muscle, the action of which is forcibly to throw forwards the fluid along the long excretory canal with which it is provided.

Cowper's glands are altogether wanting in birds. They are not found in reptiles generally; but in the amphibious *Urodeles* the genito-urinary opening is surrounded by a glandular apparatus in some respects analogous. In fishes they are wanting.

They belong to the class of glands designated by Cuvier as supplementary to the male organs of generation, and their use is to pour out a fluid to lubricate the spongy portion of the urethra, and by blending with the seminal and other fluids, to assist in the general distension of the canal.

Bloodvessels of the Urethra. — The urethra is a highly vascular membrane, and its *arteries* are derived on either side from that branch of the pudic which enters the corpus spongiosum at the bulb, and is known by the name of the *arteria corporis spongiosi urethræ vel arteria bulbi.* This artery divides into small branches, many of which are distributed on the cells of the corpus spongiosum, whilst others pass through this body, and penetrating the elastic tunic of the urethra are distributed upon its mucous surface, forming intricate plexuses between and at the basis of its columns: others are destined to the lacunæ over which they form a delicate network, which conveys to these crypts a cellular appearance. They all freely anastomose on the general surface of the urethra, and at the meatus communicate with those minute branches of the *arteria dorsalis penis*, which, having reached the prepuce, are reflected over the cutaneous surface of the glans penis.

The *veins* either communicate with those of the spongy body, and empty themselves into the dorsal vein of the penis, or terminate at once in the prostatic plexus by means of those already described in the membranous portion.

Nerves. — The nerves are exceedingly small; they accompany the arteries of the bulb, but cannot be traced into the urethral membrane, although the high sensibility of this structure even in health, and especially under disease, indicates at once a considerable nervous supply. The nerves are derived partly from the pudic nerves, which give minute branches, taking the course of the arteries of the bulb, and partly from the plexus situated beneath the neck of the bladder formed by some small branches of the sacral nerves and sacral ganglion of the sympathetic.

The lymphatics — join the superficial and deep lymphatics of the penis, and either terminate in the inguinal glands, or, passing into the pelvis with the pudic vessels, join the ganglion situated around the internal iliac artery.

Function. — The office of the urethra is to give exit to the urine from the bladder, and the secretions of the testes and their appendages the vesiculæ seminales, the prostate and Cowper's glands. For the free discharge of the urine, the urethra is in a passive condition, and the penis relaxed, and as free as possible of blood; the muscles surrounding the membranous portion together with the slightly resisting urethra yield to the efforts of the detrusor urinæ, and the urine passes in a stream varying in size and force according to the condition of the canal. If any obstruction exists either at the prostatic part, or in any other situation, the force, size, shape, or direction, of the urinary stream is altered according to circumstances; and hence, by inspection during the passage of the urine, we can often arrive at a satisfactory conclusion of the nature of the obstruction without the introduction of instruments.

When, however, the seminal secretion is to be expelled, the condition of the urethra is totally altered, and the canal is diminished in diameter but increased in length from the general distension of the penis with blood, and the consequent erection of the organ. The direction of the anterior part of the urethra is altered and straightened to the utmost; the prostatic part is raised by the action of the *levator prostatæ*, and thus forms a gentle inclination with the membranous part; and the fluid oozing through the vasa ejaculatoria is collected in the bulb, which thus becomes distended. Although it is not possible to see what is going on, yet we may imagine that at this period of the orgasm a sort of vermicular movement takes place, and that successive contractions and relaxations of the muscular apparatus of this part of the genito-urinary system occur. Thus I apprehend that the sphincter vesicæ effectually closes up the orifice of the bladder, whilst the levator ani and compressor prostatæ expel the contents of the vesiculæ and the prostate: and further, that after the bulb is distended with fluid, the acceleratores urinæ contract with considerable and successive effort, and at this moment the muscles surrounding the membranous part contracting prevent any retrogression of the seminal and vesicular secretions, and thus the contents of the urethra are forcibly expelled through the anterior part of the canal, now made rigid by the distension of the penis, and by the contraction of its own peculiar tissue, a forcible muscular effort being required to expel the somewhat inspissated fluids. The erection of the caput gallinaginis, by the distension of its erectile tissue, has considerable influence in closing up the prostatic part of the urethra, and thus assists in preventing its retrogression into the bladder.

The action of the *acceleratores urinæ* in expelling the contents of the urethra in the venereal orgasm, has been denied on the high authority of Cuvier. Kobelt believes that their sole action is to compress the bulb, and thus to force the blood onwards into the glans penis, and to increase the turgescence of this body; but that they have no direct influence either in accelerating the flow of urine as their name implies, or in the evacuation of the urethra during the act of copulation.*

There are few parts with which the constitution has a more close sympathy than the urethra: this is evinced by the general disturbance of health under the influence of diseases of this canal: thus, in inflammation from gonorrhœa, or even common causes, irritative fever is set up, persisting frequently as long as the disease lasts. So also, when in suspected or actual stricture, a bougie is passed along the canal, faintness occurs, followed by a class of symptoms resembling those of the successive stages of an ordinary intermittent. When ulceration takes place, a similar train of symptoms sets in. The same is also frequently remarked during the passage of stones, or fragments of stone, along the canal. This sympathy must be referred to the general nervous supply derived from the filaments of the sympathetic and cerebro-spinal axis. The sensibility of the urethra is not the same throughout; it is evidently more intense at the commencement, in the prostatic and membranous portions, and near the meatus, than in the spongy part generally. The pain, however, accompanying diseases of the urethra is commonly referred to the meatus, in obedience to the well-known law, that when irritation of any of the mucous surfaces produces pain, this is principally felt at the point where the mucous and cutaneous systems blend into one another, namely at the outlet of the mucous canal.

Development. — The development of the male urethra is a subject of considerable interest both in a physiological and pathological point of view, as a comprehension of the phenomena attending it enables us to offer a ready explanation of those curious malformations to which this canal is not unfrequently liable.

For the description of the development of the intra-pelvic portion of the urethra from the uro-genital sinus, the reader is referred to the article Prostate, in which the separation between the bladder and rectum in the male, and the bladder, rectum, and vagina of the female, is considered; and we have, therefore, now only to trace the growth and extension of that portion of the urethra which traverses the body of the penis.

Up to the end of the fifth or beginning of the sixth week, the external organs of generation in the male resemble those of the female, and a common opening or cloaca exists, into which the rectum, bladder, and genital organs terminate. At the anterior part of this common outlet a small projection is formed, presenting a concavity below, along which there runs a superficial groove towards the anus. This corresponds to the clitoris in the female, and the penis in the male. A slight enlargement now takes place at the extremity, which becomes the glans. In the female the two sides of the groove begin to swell out, and become the *labia majora*. A separation now takes place between the openings of the anus and vagina, and the perinæum begins to be formed. The opening of the uro-genital canal is a small aperture in front of the anus, at the extremity of a slit, which proceeds as far as the root of the penis or

* Die Männlichen und Weiblichen Wollust-organe des Menschen, &c. Von Kobelt. Freiburg, 1844.

clitoris, and becomes surrounded by two folds of skin which form its sides.

In the male, the two folds of skin which correspond to the *labia majora* become blended together, and form a projecting ridge, called the raphé; they also form the scrotum. The penis continues to increase in size, but the groove which runs along its under-surface as far as the glans, remains patent until the fourteenth or fifteenth week, when its sides swell out and adhere together, and hence the urethral canal, which is completed about the fifteenth week. The prepuce is formed at the fourth month, and at this period the orifice of the urethra appears in the form of a small slit at the extremity of the glans, but it is completely closed at first.

At the period of birth the pelvic portion of the urethra is more vertical than in the adult, in consequence of the position of the bladder, a great part of which is now situated in the abdomen; the bulbous portion is situated at a greater distance from the anus than afterwards.

The rudiments of Cowper's glands are formed at a very early period, on each side of the genito-urinary passage.

PATHOLOGY. — Under this head are included, first, all deviations from the normal condition arising from arrest of development; secondly, all changes in the direction and condition of the urethra depending on disease. The first are necessarily congenital, the second acquired.

Congenital malformations. — The urethra is seldom altogether absent: it is, however, wanting in cases of decided cloacal formation, and in the female, where there is partial deficiency of the bladder (ectrophy); but in those cases in which the urachus remains patent, and where the urine is discharged by this canal, the urethra is always met with.

The urethra sometimes runs along the dorsum of the penis in the form of a broad groove. This malformation is termed *epispadias*, from the Greek word ἐπισπάω, in contradistinction to *hypospadias*, from ὑποσπάω, *subtraho*, as in the latter malformation the penis is drawn down.

Epispadias is frequently complicated with ectrophy of the bladder, but often exists independent of this congenital malformation.

In either case there is generally considerable diastasis of the symphyses pubis, the bones being united together by a long intervening ligamentous structure. In epispadias there is also a deficiency in the superior part of the prostate gland, the lobes of which are seen only below, and the veru montanum is found in its usual situation; the prostate is generally smaller than common; the penis also is but imperfectly developed. The urethra itself forms a mere superficial channel along the dorsum penis; it is copiously supplied with large lacunæ, the corpus spongiosum is wanting above, and the glans is cleft; the prepuce ceases at the corona glandis.

In a case which I recently examined, the bladder was small, and, as if to supply the deficiency in the muscular apparatus of the membranous part of the urethra, which was necessarily wanting, the acceleratores urinæ were immensely developed; their superior attachment was of course deficient.

Hypospadias implies that form of malformation in which the urethra runs in a groove beneath the penis; it is subject to considerable variation. The most common variety is that where the urethra forms a simple groove, and the penis is bent downwards, the prepuce being wanting. If this groove be continued down deeply to the perinæum, between the two sides of a fissured scrotum, the whole genital system takes on more or less of the female character, and hence has arisen the false notion of the subject of hermaphroditism.

There are many modifications of this malformation. Otto * mentions one case where the penis was cleft, and the vestige of the divided urethra was easily recognised, a fossa navicularis being distinguishable on either side, as well as the termination of an ejaculatory duct. The prostate was wanting. Sometimes the urethra is perfect in the glans, and throughout the remainder of its course it is open beneath the penis.

The urethra sometimes *terminates before it reaches its usual destination.* Thus it opens into the rectum, or into the perinæum; in other cases it goes no further than the root of the scrotum; sometimes it ends at the corona glandis, or it may end at any distance between this body and the bulb. Occasionally the *opening is altogether wanting* (*atresia urethræ*), or it is covered by a delicate fold of skin. When it terminates in any of these unusual situations, the opening is very small, sometimes so small as not to admit the introduction of a bristle. Now and then we meet with a rudimentary meatus in the usual situation, terminating in a *cul-de-sac,* and beneath this a small urethral orifice. When the urethra ends at the corona glandis, the prepuce is imperfect; it is thrown into a fold resembling the hood of a monk, and is hence denominated the *monk's hood* prepuce, and the glans is uncovered.

Deviations in diamater, although occasionally congenital, are generally the result of disease. A preternaturally contracted state of the urethra is sometimes found at birth. This may happen at the orifice as before mentioned, or in other parts of the canal. Under this condition, the bladder, ureters, and pelves of the kidneys are sometimes dilated, as in ordinary cases of stricture.† Congenital stricture of the urethra is nevertheless exceedingly rare.

Diseases and accidents.—*Dilated urethra* is not uncommon as the consequence of stricture. When the bladder is unable to get rid of its contents, the inordinate efforts to overcome the resistance occasion sometimes a gradual dilatation of the urethra behind the seat of stricture. This condition is at-

* Monstrorum Sexcentorum Descriptio Anatomica.

† See article TERATOLOGY.

tended with excessive irritation along the whole course of the canal, and the prostate gland becomes hypertrophied in consequence. Sir Benjamin Brodie mentions a remarkable case of this description. In this case the urethra, behind the obstruction, was so dilated, that, whenever the patient attempted to pass his urine, a fluctuating tumour, as large as a small orange, was felt in the perinæum. It was punctured, and immediately the urine gushed out in a full stream.

The escape of calculi from the bladder often occasions dilatation of the urethra into pouches; and such dilatations occur independent of ulceration.

On dissection of these pouches, the mucous membrane is usually found injected and thickened, presenting fungous vegetations, and occasionally coated with lymph.

The urethra deviates frequently from its normal direction: thus, in large scrotal herniæ, and hydroceles of large size, it takes a serpentine course: so also, when tumours press on the canal, its course is altered. The same happens in enlargement of the prostate gland, and from the projection of its middle lobe, the urethra divides itself into two streams. Abscesses also distort the canal from its natural direction. Tumours in the pelvis, as a collection of hydatids between the bladder and rectum, in consequence of the influence they exert on the bladder, frequently distort the urethra from its normal direction. This distortion occurs more especially to the pelvic part of the canal. Under these circumstances the urethra is generally lengthened to a greater or less extent.

Solutions of continuity result either from mechanical injury, or from disease. The urethra may be wholly or in part divided. Most commonly, if the division be incomplete, a small fistulous opening remains for a short time, which subsequently, if let alone, completely closes. Incisions through the membranous part of the urethra, as in the operation of lithotomy, speedily cicatrise.

The most serious injuries to the urethra are those resulting from blows or falls on the perinæum, especially when they are accompanied by fracture of the *ossa pubis*. In these cases there is either partial or complete solution of continuity. The membranous part of the urethra, from its position beneath the pubic arch, most frequently suffers. The nature of the injury may be generally recognised by the escape of blood with the urine, or by complete retention of urine. An elastic catheter, carefully introduced, will in the former case generally grate against the torn part In complete division of the urethra, if the patient survive the injury, the torn ends are, in the progress of the cicatrisation and contraction, brought into apposition, and the continuity of the tube is restored: stricture is the almost necessary consequence. If, however, the cure is not accomplished, urinary fistula is the unfortunate result. When the complete division of the urethra is accompanied with fracture of the pubis, the two ends of the canal are frequently so completely separated, that extensive extravasation of urine ensues, and the case is generally fatal.

Severe contusion of the urethra, independent of rupture, sometimes leads to ulceration or sloughing, and occasionally gives rise to stricture by inducing chronic inflammation of the injured part.

Laceration of the urethra occasionally happens from the introduction of foreign bodies, or from the escape of fragments of calculi, especially after the operation of lithotrity. The torn part generally heals under simple treatment, or the urine is infiltrated into the spongy body, and abscess is the consequence. Laceration often attends violent efforts to force a stricture with the sound or catheter: these injuries usually happen at the under part of the canal, and frequently heal if all violence be desisted from. In a case of lacerated urethra brought into the London Hospital, a large pouch as big as a small orange was formed in the scrotum, into which, when the man attempted to micturate, the urine was forced; he then squeezed it through the natural passage. By degrees this pouch gradually contracted, and no vestige of it remained.

Inflammation of the urethra, whether common or specific, is usually of the catarrhal form: common inflammation is comparatively rare; but it may be excited by chemical and mechanical stimuli, or it may depend entirely on constitutional indisposition: thus strong injections have been known to induce every symptom of severe urethritis simulating an attack of gonorrhœa; but the disease is speedily arrested by ordinary antiphlogistic treatment. Under the head of mechanical causes may be enumerated the introduction of the catheter or bougie, and other foreign bodies, and the passage of calculi entire or in fragments, and blows on the perinæum.

The urethra is sometimes inflamed from constitutional causes, or sympathetically: thus stone or calculus in the bladder and kidneys frequently leads to urethritis; some substances taken into the stomach produce the disease, as asparagus, cantharides, and turpentine, and arsenic if administered in large doses, especially if the poison be allowed to accumulate in the system.

In persons of a gouty diathesis, urethritis occasionally occurs, followed by a discharge of muco-pus. According to Prout, "gouty irritation of the urethra often assumes all the characters of gonorrhœa, and is not only attended by a profuse discharge, but with great irritation and scalding in passing water." During the prevalence of influenza, I have witnessed a severe attack of urethral inflammation accompanied with copious puriform secretion, and attended with the ordinary symptoms of clap; under the influence of a purge it passed off entirely in a few days. Suppression of cutaneous eruptions, according to the German pathologists, not unfrequently causes urethritis. Inordinate indulgence in venery, and masturbation, produce inflammation of the urethra by the constant irritation of the part. So also the irritation of the menstrual and leucorrhœal discharges, when applied to the male urethra under states of high excitation, induces a similar pathological condition.

Croupal exudations are sometimes found in the urethra. These assume either a tubular form, or the lymph is effused in the form of long shreds.* The mucous follicles situated in the vicinity of the meatus are, according to Kleeberg, of Königsberg, liable to a form of inflammation similar to that which attacks the follicles of the genital organs of the female. He thinks that it is sometimes connected with clap, or gleet, and often independent of either. It is indicated by a swollen state of the circumference of the mouth of the urethra, which is of a brownish red colour. There is slight pain in making water. The orifices of the lacunæ become closed by inflammation, and, in the course of two or three days, pustules are formed in their places, which break and discharge a yellow pus. "The orifices of the large mucous follicles are now seen dilated and surrounded by a swollen dark-red border, and they discharge a muco-purulent fluid into the urethra: if this be washed off, and the glands compressed, the fluid is distinctly seen issuing from these openings." † The disease sometimes assumes a chronic form.‡

The specific causes of inflammation of the urethra are syphilis, gonorrhœa, and small pox. Of these, gonorrhœa is the most frequent. Syphilitic inflammation, producing chancre, is by no means unfrequent, as Ricord has proved. The disease makes its appearance on the 6th, 8th, and 12th days after connection. Inoculation from the discharge produces the true syphilitic pustule. It often attacks the meatus urinarius.

Inflammation from gonorrhœa may be either acute or subacute, or the disease may be virulent or simple, the difference being in degree rather than in kind. The disease begins in the anterior part of the canal, and is supposed to attack first the lacuna magna. Hunter limited its specific extent to an inch and a half from the meatus. The period of incubation of the poison varies from one to ten days, and is sometimes prolonged even beyond this, if we can believe the accounts of patients. Hunter has known it to appear a few hours after connection, and Sir Astley Cooper met with a case in which it did not make its appearance until after fourteen weeks from the time of inoculation.

The pathological changes in the urethra from this disease may be briefly described. The disease, commencing at the part indicated, if left to take its own course, gradually extends itself in a retrograde direction as far as the neck of the bladder, and, in very severe cases, the mucous membrane of this viscus becomes involved. The urethral membrane is swollen, red, and exceedingly vascular: this can only be generally observed at the orifice, but it has also been seen in the middle of the canal in cases where, during an attack of gonorrhœa, the urethra has been divided. The intensity of the inflammation is not uniform. Thus, the lacuna magna, and the beginning of the spongy portion, are most severely attacked. The inflammation attacks the lacunæ, giving rise to pain and swelling in various parts of the canal; even the spongy body itself becomes, by contiguity, implicated in the disease, and interstitial deposition of fibrin takes place in its cells, causing unequal distension of this body during erection, and hence painful *chordee.* Abscess in this body is not very unfrequent. By continuity of surface, the disease attacks the mucous lining of Cowper's glands and the ducts of the prostate, whilst through the ejaculatory vessels it passes to the vesiculæ seminales, and by the vasa deferentia to the epididymis, causing *hernia humoralis.* When the latter structures become affected, the inflammation of the urethra itself in a great measure subsides, and the discharge ceases, usually to reappear in a mitigated form.

The inflammation of gonorrhœa is necessarily of the catarrhal character. At the first onset of the affection there is a slight weeping from the meatus of a transparent fluid, in which mucus particles are floating, probably only the natural secretion of the urethra in excess. This soon gives place to a semi-puriform secretion, which glues the edges of the orifice together. It afterwards becomes more distinctly puriform, and at the height of the inflammation, the discharge, which has increased in quantity, puts on a greenish hue, and is of a faint, sickly odour, as the disease subsides. It changes again as to its character in exactly the inverse order of its appearance. It frequently leaves behind it a gleety discharge. The seat of this discharge in gleet is either the general mucous surface of the urethra, the lacunæ, or the anti-prostatic ducts, and in many instances the ducts of the prostate gland are alone affected in long persistent gleets.

When gonorrhœa coexists with chancre, the discharge has usually a greyish or reddish tint, or sanious aspect.

Among the most important consequences of this affection, we may mention simple erosion and cicatrices from ulceration producing stricture, and, which is much more common, chronic thickening of the urethra giving rise to stricture. If the diseased urethra be examined after death, according to Hunter, the fossa navicularis and its lacunæ are found more vascular than usual, and the lacunæ filled with matter. In more severe cases the membranous part, Cowper's glands, and their ducts, are involved in the disease. Littre found, after examining forty cases, Cowper's glands morbid in one only; and Morgagni met with only one or two instances of a

* See Pathological Museum of the College of Surgeons, Preparation No. 2576.

† Zeitschrift für die gesammte Medicin, Band ii. Heft 2.

‡ British and Foreign Med. Review, vol. iii.

similar kind. The prostatic part of the urethra evinces signs of disease in severe attacks of clap.

The glands of Cowper are sometimes inflamed, independent of gonorrhœa, and become indurated; or they occasionally suppurate.

Ulceration of the urethra may arise from common and specific causes. In the latter category, chancres take the first rank; these can only occur in the anterior part of the canal, and are generally found at the urethral orifice.

Ulceration, independent of specific cause, is sufficiently common: thus, it may arise spontaneously, or as the consequence of stricture, or foreign bodies in the canal, as calculi, pieces of bone, bougies, &c. Spontaneous ulceration of the urethra is exceedingly rare; it is not mentioned, usually, by writers on the diseases of the urethra. I have met with one instance of it myself: in this case three successive attacks of ulceration had occurred, which terminated in urinary fistulæ, one anterior to the scrotum, one in the perinæum, and one in the vicinity of the tuber ischii. They were each preceded by rigors, and other signs of fever, and were accompanied by much constitutional disturbance; no stricture, or other appreciable disease of the urethra whatever, had preceded the ulcerative process.

Ulceration behind a stricture is very common; it depends on inflammation attacking the part as the result of long continued irritation.

A stricture itself sometimes becomes the seat of ulceration, when bougies and catheters are used with violence for its cure. It also happens, though rarely, that spontaneous ulceration of the stricture occurs, by which the stricture is cured. Sir Benjamin Brodie relates an instance of this.

Ulceration consequent on tubercular deposit now and then occurs in the urethra, but only in cases where tuberculosis prevails over the entire urinary apparatus.* An instance of this description occurred to Mr. Robinson of Peckham, in a man who had been the subject of extensive tuberculosis in the urinary and genital organs. The disease appears to attack the follicles.

Cancerous ulceration attacks the male urethra in carcinoma of the glans penis and other parts of the organ.

Sloughing of the urethra, as a consequence of stricture and violent catheterisation, often leads to the destruction of a considerable portion of the canal.

In severe cases of small pox, pustules are not unfrequently found in the urethral membrane.

Abscesses.—As a consequence of inflammation, abscesses form in connection with the urethra: they may be acute or chronic: sometimes they communicate with the urethra, but frequently they have no such communication. Abscesses may take place in any part adjacent to the canal: thus, in severe gonorrhœas, suppuration in the spongy body from inflammation of contiguous parts is not very uncommon; the same also is occasionally met with in the perinæum, in Cowper's glands, and even in the prostate. Abscesses are not unfrequently met with as the consequence of injury to the urethra from blows or falls upon the part. In all such cases the abscess communicates with the canal, and frequently, if not generally, is attended with extravasation of urine.

The most common forms are those depending on stricture; they are preceded by ulceration or sloughing, which generally takes place behind the seat of stricture. Syme thinks that ulceration of the urethra is secondary to the formation of matter, which is external to the urethra, and precedes the ulceration. Abscesses now and then form in the vicinity of the urethra without any direct, or indirect communication with the canal; this happens occasionally in cachectic states of the constitution, in which abscesses are not unfrequent in the vicinity of other mucous outlets, as the rectum. When these are opened, the matter is disgustingly fœtid, and is strongly impregnated with an urinary odour, although no urine has become mixed with it, no breach having occurred in the urethral membrane.

One of the most common forms of abscesses connected with the urethra arises from inflammation of the lacunæ during a severe attack of gonorrhœa. Under these circumstances the orifice of the lacuna, the subject of the disease, probably becomes closed by adhesive inflammation, a small, round, indolent tumour is formed in the direction of the spongy body, or in the perinæum. Ulceration or bursting into the urethral canal often occurs, and the urine escapes into the sac, causing increase of inflammation; and now distinct suppuration having taken place, fluctuation becomes evident, and either the matter escapes externally by ulceration, or the surgeon is induced to puncture it with a lancet.

Tubercles.—Louis states that he has rarely examined the urethra of tuberculous subjects. Rayer, however, quotes two cases, one of which he witnessed himself, and the other was communicated to him by Vernois. The former occurred in a man thirty-six years of age, who had tubercles in his kidneys, testicles, and prostate; the latter in a boy, aged twelve, with tubercles in the kidneys and on the surface of the peritoneum; in this case the whole urethra was apparently affected; in the other, only two inches and four lines of the vesical end were diseased.

Ricord presented to the Academy of Medicine* a curious specimen of an urethra completely studded with miliary tubercles. It was removed from a man who had undergone the operation of castration for tubercular deposit in the testicle some years previously. The prostate contained a tubercular excavation.

* See Rokitansky.

* Séance du 2 Avril.

The urethra is sometimes traversed by cords, in some respects resembling at first sight the *cordæ Villisii* of the longitudinal sinus. I presume they are formed by organisation of effused lymph. There is a curious specimen of this disease in the Museum of St. Bartholomew's Hospital, marked in the Catalogue 30. 37. The patient from whom the preparation was taken had been frequently the subject of catheterization. The disease is exceedingly rare.

Stricture.— Under this head are enumerated all contractions of the urethra depending on alteration of the tissue of the canal itself, or the parts immediately surrounding it. Strictures are commonly arranged under three heads—spasmodic, permanent or organic, and inflammatory or irritable stricture.

A *spasmodic stricture* may be defined to be a temporary diminution in the diameter of the urethra, sometimes to such an extent as to effect its complete closure, from spasm of the muscles surrounding it. The term can only, with strict propriety, be applied to a temporary contraction of the muscles investing the membranous portion, as no action of the acceleratores urinæ is equal to the complete closure of the spongy part. The common seat of spasmodic stricture is therefore the membranous part.

Spasm of the urethra arises from various causes, as exposure to cold, indulgence in wine and venery, and gonorrhœal inflammation. So also, certain medicines, as cantharides, when taken into the stomach, or applied endermically, may induce a similar condition.

Although genuine spasm is confined to the membranous part, yet the remainder of the urethra is liable to temporary contraction from general irritation of the mucous surface, as where the urine is loaded with lithates, and hence becomes exceedingly irritating. Under these circumstances the stream of urine is diminished, and the urethra resists the introduction of the catheter. This condition probably depends on irritability of those fibres, be they muscular or not, which enter so largely into the structure of the outer layer of the urethra.

Spasmodic stricture may be recognised in the following manner: a patient observes a sensible diminution in the stream of water, aggravated by drinking and free living. After unusual indulgence in wine or venery, he finds suddenly that he is unable to pass a drop of water; the surgeon, on attempting to introduce an elastic catheter, which is the best adapted for the case, finds the progress of the instrument impeded at the membranous part of the urethra; by gentle pressure, however, the spasm yields, and the instrument enters the bladder suddenly, and all sense of contraction disappears. On using the instrument on the following day, he finds that it passes with perfect freedom.

By *permanent stricture* is understood a narrowing of the canal from organic change in the tissue of the urethra itself, or the corpus spongiosum. Permanent stricture may attack any portion of the urethra; even the prostatic part, the fossa navicularis, and the bulb have been the seat of stricture: thus, Ricord and Cross have met with stricture in the prostatic portions, and the fossa navicularis has been found to be the seat of the disease (after ulceration); but, although it is by no means unfrequent in the spongy portion, it is most common in the anterior part of the membranous part of the canal. This subject has been examined by various writers on urethral diseases, but the most extended researches are those of Mr. Phillips, and I therefore append the result of his observations. He selected a number of cases for examination, and he found that

In 9 cases the stricture was distant from the meatus	-	-	-	1 inch.
8	„	„	from	1 to 2 inches.
13	„	„		2 to 3
11	„	„		3 to 4
98	„	„		4 to $5\frac{1}{2}$
40	„	„		$5\frac{1}{2}$ to $6\frac{1}{2}$
10	„	„		$6\frac{1}{2}$ to $7\frac{1}{2}$

This corresponds with the observations of Ducamp, who found that, in five cases out of six, strictures are found at the distance of about 5 inches from the meatus, or from 4 inches 9 lines to 5 inches 3 lines. Amussat states that the most common seat of the disease is the point of junction between the bulb and membranous portions.

Varieties of permanent stricture.— Strictures may be spontaneous or traumatic. *Traumatic strictures* generally occur at the membranous portion, but they are occasionally found in the spongy part. The former result from contusions or lacerations, the latter from division of the canal by cutting instruments, as after the extraction of impacted calculi, or after complete division. Whatever be the cause of traumatic stricture, if stricture ensues after a wound of the urethra, a cicatrix occurs, as in other situations, and a tendinous puckering of the membrane takes place, giving rise to the most intractable form of the disease. If, however, the stricture results from simple contusion inflammation attacks the part and the stricture is produced as in the common class. After ulceration of the urethra from chancre a puckering of the membrane gives rise to stricture in its character resembling the ordinary traumatic variety.

The most simple form of permanent stricture is where the urethra is traversed by a fold of membrane thrown across in the form of a bridle. In this case the stricture is usually in the floor of the canal. It may occur in any part, except the prostatic, but its usual seat is the commencement of the spongy portion. The diameter of the urethra is thus only partially occluded, the shape of the stricture being somewhat crescentic. When the urethra is completely encircled, it appears as if a slender thread were tied around it, and thus an *annular* stricture, or bridle, is formed, the opening being usually in the middle. The efforts to micturate often push forward the strictured part, thus inducing a valvular appearance. Authorities vary as to the formation of this stricture. Some, as Ducamp and Laennec, believe it to depend on the organisation of false membrane thrown out on the mucous surface. Amussat attributes it to the healing of an ulcer, but there can be little doubt that both causes may give rise to a similar condition. Arutzenius considers it due to a swelling of the mucous membrane, and consequent loosening from the subjacent tissue : thus the membrane becomes wrinkled, and a fold is formed on its surface.

Hunter attributes the origin of these strictures to spasm of the circular muscular fibres of the urethra. Sir C. Bell describes them as occasionally splitting into branches, and running in a longitudinal rather than a circular direction. He considers them as the result of inflammation of the mucous surface : to this opinion most modern surgeons subscribe. Sometimes two or more annular or bridle strictures coexist at short intervals in the same urethra. Hunter met with six, Lallemand seven, and Calot as many as eight.

The next variety of permanent or organic stricture is that in which the urethra is narrowed to a much greater extent of its course than in the former case. In these cases half an inch or an inch, or even the whole extent of the spongy part of the urethra, is more or less contracted. The stricture occupies one or other side, or it completely encircles the tube. It varies in consistence, from a soft, yielding thickening of the membrane, to a complete cartilaginous hardening. The disease in its most simple form occupies either the mucous layer alone, or the submucous elastic layer ; but it is not limited to this, for in many cases the tissue intervening between the submucous layer and the spongy body is the seat of disease, whilst in others even the spongy body itself, whose cells are obliterated by the deposition of lymph, becomes thickened and indurated, and thus encroaches on the urethral tube. I regard genuine simple stricture as dependent on hypertrophy of the mucous or epithelial layer and the submucous elastic lamina of the urethra.

Stricture in its progress passes through various stages, from simple thickening to complete cartilaginous induration. The complete cartilaginous conversion of stricture is more frequently found where the stricture is situated in the spongy portion.

The most intractable stricture is that which results from ulceration of the meatus ; it is frequently associated with adhesion of the prepuce to the glands; sometimes the strictured part will not permit the passage of a bristle. For the cure of this disease incision is necessary.

Among the most common attendants on stricture of the urethra are hernial protrusions of the mucous membrane of the bladder, between the columns of the *detrusor urinæ*, in the form of sacculi. As a consequence of stricture of the urethra, may be mentioned rupture of the canal and of the bladder itself. It is probable that these are preceded by interstitial absorption, and not unlikely by sloughing or ulceration. And the straining to overcome the impediment to the exit of the urine leads frequently to the formation of hernia at the groin, and has been attended with rupture of the rectus abdominis muscle.*

In old strictures the membrane of the urethra is usually hypertrophied, the orifices of the lacunæ are enlarged, and the prostatic ducts considerably dilated. The prostate gland itself is frequently hypertrophied in consequence of the general irritation of the urethra.

False passages. — A false passage may be formed in any part of the canal, according to the seat of stricture; there may be one only, or several may co-exist. The under part of the urethra usually gives way, owing to the direction given to the point of the catheter. Sometimes the catheter, passing beneath the stricture, re-enters the urethra, and is then directed into the bladder, or it may be forced onwards through the prostate gland ; occasionally the catheter penetrates but a short distance, and on withdrawal enters the natural passage. False passages through the third lobe of the prostate gland not unfrequently result from unskilful attempts to relieve retention of urine from enlarged prostate; in this way the gland may be perforated in three or four places.

When false passages are maintained by the frequent attempts to pass the catheter, they become lined by a mucous membrane, and the urine is in some ever afterwards discharged through the newly formed canals.

Fistulæ in perinæo (urinary fistulæ) — are a common consequence of ulceration behind a stricture ; they are generally preceded by abscess, and sometimes by gangrene. Not unfrequently they arise independently of any obstruction, as after abscess from acute gonorrhœal inflammation. Urinary fistulæ result also from wounds of the canal, as after the operation of lithotomy, or the extraction of calculi from the urethra. Suppuration of the lacunæ sometimes leads to urinary fistula: this happens occasionally to the lacuna magna.

In urinary fistula there is sometimes a single opening into the urethra, with many external openings. These are found in various situations: thus they occasionally exist anterior to the scrotum, sometimes in the perinæum, and now and then they open into the rectum, or even as low down as the tuberosities of the ischia : the external and internal openings do not always correspond, the intervening tract taking a tortuous course. The walls of the fistula are much thickened and indurated, and this induration extends for some distance to the parts around, and involves a large extent of the cellular tissue and skin, so that the perinæum feels as hard as cartilage : the canal of the fistula is lined by a mucous membrane.

Sometimes the fistula passes upwards to-

* See Dublin Journal of Medical Science, May 1842, p. 308.

wards the pubis, and gives rise to inflammation and caries of the bone; nay, it may take its course even to the groin and lower part of the abdomen.

For obvious reasons, stricture seldom happens prior to puberty; nevertheless some rare instances are recorded of the disease in young children. I do not here allude to such as result from mechanical injury, for these may happen at any age. Hunter mentions a case of stricture accompanied with fistula in perinæo in a boy four years old, but he does not speak of the cause.* He also mentions one in a boy eleven years old. In the Museum of the College of Surgeons there is a preparation (No. 2535.) of the bladder and penis of a boy seven years of age, laid open to show a stricture at the membranous part of the urethra, and behind the stricture a small stone is lodged. The case occurred to Sir E. Home, who also mentions a case of stricture occurring at ten years of age.

What is the true nature of a stricture? I believe that a stricture (I speak of the permanent class) may result from the organisation of lymph effused upon the surface of the mucous membrane, as in the formation of bridle strictures. Secondly, that it may arise from the healing or cicatrisation of an ulcer, in which case a fibrous puckering is produced. Thirdly, that it may arise from hypertrophy of the elastic layer beneath the mucous membrane. Fourthly, from deposition of lymph between the urethra and spongy body; and, lastly, from deposit and organisation of lymph in the cells of the spongy body; and that these conditions may all co-exist.

When the strictured part is laid open, it will be found that at the exact seat of stricture the mucous surface is raised; and beneath this the submucous elastic lamina is observed distinctly thickened, of a firm texture, and deprived more or less of its natural elasticity, this thickening passing off gradually and insensibly in a longitudinal direction until it altogether disappears and the canal resumes its natural diameter, or is dilated or contracted according to circumstances. The thickening usually extends equally around the urethra, so that the opening of the canal is in the middle of the stricture, but in some instances it is confined to one side. On attempting to dissect the urethra from the subjacent spongy body, it will be found that its adhesion at the seat of stricture is so complete, that it cannot be raised without much difficulty, and in many cases the separation of the two structures cannot be accomplished at all. The spongy body itself is frequently thickened, and the delicate tissue forming the septa of its cells is much hypertrophied.

Causes of stricture. — Most strictures are the result of inflammation of the urethra. Long persistent and neglected claps constitute by far the most common of the causes of the disease. I have no hesitation in admitting that the indiscriminate use of stimulating injections may be fairly set down as the occasional cause of stricture. Masturbation, and the too frequent indulgence in the venereal act, may be enumerated amongst the occasional causes of the disease.

Co-existence of stone with stricture. — It often happens that calculus in the bladder co-exists with stricture in the urethra, and the connection between the two diseases appears easily accounted for. But some curious circumstances occasionally occurring in these cases, render it very doubtful whether we are justified in indiscriminately attributing the formation of stone to the impediment to the discharge of water from the stricture; nay, the circumstances to which I allude rather tend to prove the converse of the proposition, namely, that the stricture depends on the irritation in the urethra, maintained by the presence of stone in the bladder. The inference appears legitimately deducible from the fact, that cases of severe stricture have been entirely cured by the removal of the stone from the bladder by lithotomy.*

Diseased lacunæ. — Sometimes one of the lacunæ becomes the seat of chronic inflammation, and is converted into a small indurated tumour, varying from the size of a hemp-seed to a horse-bean. It becomes imbedded in the spongy body.† According to Sir B. Brodie, the usual situation is about two or three inches from the orifice, but it is sometimes perceptible close to the frænum, at others within the scrotum.

Rokitansky mentions a curious form of disease occurring after repeated attacks of gonorrhœa. "The urethra presented numerous cartilaginous protuberances, from the size of a millet-seed to that of a pea, in part coalescing, and scattered over the inner surface as far back as the bulb, leaving the passage, however, of adequate dimensions." ‡

Obstruction from other causes.— The urethra is sometimes occupied by verrucous vegetations, the result of gonorrhœa. Numerous instances of this are given by Ricord; they are usually found near the meatus, and are remarkably vascular; but sometimes they exist in the membranous, or even the prostatic, portion. They are distinguishable by their greater vascularity from another form of *excrescence* or *caruncle*, which co-exists occasionally with stricture. Both, however, are formed in consequence of irritation of the urethral membrane, and represent simple organised structures connected with the urethra by a base or stem.

Hunter met with two, and these were in cases of very old stricture, where the urethra had suffered considerably. Home says, that with all his opportunity in inspecting these diseases in the dead body, he never met with them. Rokitansky § also affirms their extreme

* Hunter, On the Venereal Disease, p. 115.

* See Edinburgh Monthly Journal for April, 1850, p. 367.

† Home, On Strictures.

‡ Rokitansky's Pathology; Sydenham Society's edition, vol. ii.

§ Loc. cit.

rarity. Chelius* says, "they are found as little masses of soft warts behind the stricture; at other times they are found before the stricture; they are similar to those growths observed on the prepuce and glans. I have seen in one person, who had frequent claps, the urethra filled with round excrescences from an inch behind the *fossa navicularis*." Morgagni found one in a case of stricture.†

These excrescences are developed from the mucous membrane as the result of simple as well as specific irritation, and are limited in the extent of their growth by the walls of the canal.

We sometimes meet with a more perfectly organised structure in the urethra in the form of polypi. They, however, are by no means common. Rokitansky met with one in the prostatic part of the urethra, in which situation they are usually found.

In the Museum of the Royal College of Surgeons there is a preparation (2578.) of the urethra of an ox, with a large polypus hanging from the verumontanum.

Irritable Urethra.—This condition may be recognised by the following symptoms: there is slight increased vascularity of the canal as indicated by the redness of the meatus: the lips of the meatus are glued together in the morning by mucus, slightly tinged: there is a very trifling discharge, scarcely sufficient to discolour the linen; this is increased by indulgence in wine; a sense of uneasiness is perceived along the canal, and this extends to the testicles and the rectum. The patient has a more frequent desire than natural to pass his water, the stream is diminished, and a scalding sensation is experienced at the extremity of the glans whilst the urine is passing. These symptoms are exacerbated by indulgence in venereal pleasures, and are often associated with increased acidity of the urine; not unfrequently pain is experienced down the thighs in the course of the nerves, and the patient suffers a slight febrile attack. This state exists, very frequently, altogether independently of gonorrhœa, and appears really to result from a mental cause, the patient being strongly impressed, after a suspicious connection, with the idea of impending gonorrhœa. Under the use of diluents and the warm bath this disease very generally passes off. The true pathology of this state I believe to consist in an increased vascularity of the urethra and its follicles, with a similar condition of the glands of Cowper and the prostate, under the influence of nervous irritability.

The prostatic part of the urethra is liable to irritation from long continued masturbation. The orifices of the ejaculatory ducts are the special sources of this irritation, but the general mucous surface around partakes of the disease.

Neuralgia of the Urethra.—The urethra and neck of the bladder are consentaneously affected in this disease. The periodic and remittent forms of neuralgia attack the urethra: the periodic disease is characterised by deep shooting pains in the canal extending over the loins and sacrum, and down the thighs, occurring in paroxysms, and generally accompanied by sudden and urgent desire to micturate. The attacks recur at a certain hour, generally night and morning, or every second or third day, and during the intermissions the patient is altogether free from pain.

The urine is thrown out in jets, and sometimes stops suddenly, and many of the ordinary symptoms of stone in the bladder are present, and hence the great importance of the diagnosis, for there is no doubt that, under this condition, many patients have been subjected needlessly to the operation of lithotomy. The sound alone can decide the question. This disease may originate entirely from the ordinary causes of neuralgic affections, or it may depend on local causes, as the use of stimulating injections, the frequent use of the catheter, constipated bowels, worms in the rectum: it is often associated with acrid urine, and either leads to, or is accompanied with, hypertrophy of the *detrusor urinæ*.*

In the female.—The female urethra is a short tube by which the urine alone is excreted. It commences at the neck of the bladder, and terminates at the meatus urinarius. The direction of the urethra in the female is similar to the first or pelvic division of that of the male; thus it descends slightly, and, passing forwards, in nearly a straight direction, beneath the pubis, it makes a gentle ascent just at its termination: it therefore forms a curve, the concavity of which faces upwards, the convexity downwards, towards the anterior wall of the vagina, in which it appears imbedded, and to which it is so closely connected, that it is almost impossible to separate one from the other. In its course it perforates the triangular ligament, which is stretched across beneath the arch of the pubis, and is but an imperfect representative of the corresponding part in the male. The urethra thus forms the first and smallest of the three outlets beneath the pubis.

The commencement of the urethra is situated within the pelvis, behind the symphysis pubis, to which it is suspended by the apparatus which supports the neck of the bladder: its next division is directly beneath the inferior pubic ligament, and is connected to it by condensed cellular membrane: the last portion of the urethra passes between the origins of the crura clitoridis, and terminates by a rounded aperture at the anterior part of the vagina, and a little in front of the pubic arch: this aperture is called the meatus urinarius.

The female urethra is invested by a muscular apparatus, analogous to that surrounding the membranous portion of the male canal: thus Santorius described some tranverse and circular fibres connected with this part, the latter being situated deepest, and the former

* Chelius' Surgery, translated by South, vol. ii. p. 356.

† Liv. xix. ch. 23.

* Rowland, On Neuralgia.

passing over the canal, and termed by him "the *depressor urethræ*." So also often vertical fibres can be distinguished arising from the back of the symphysis pubis, and analogous to Wilson's Muscles, in the male. Guthrie * also has given a representation of a muscle arising from the rami of the pubis, and splitting into an upper and under part, and thus completely surrounding the tube, as the muscle known by the name of "Guthrie's muscle" does in the male: this apparatus in the female can only have the effect of effectually closing the canal. The length of the female urethra varies from an inch and a half to two inches; but its diameter is considerably greater than that of the male urethra: thus at its commencement, at the neck of the bladder, it is nearly half an inch in diameter, but it is nearly cylindrical in the remainder of its course, and does not exceed three or four lines in diameter. It is contracted at the meatus urinarius. There are few points of higher practical importance in reference to the surgery of the urinary organs of the female than the extreme dilatability of the urethra. It is well understood that, by the introduction of sponged tents or other mechanical contrivances, gradually increased in diameter, this canal may be so far dilated as readily to permit the extraction of urinary calculi of at least an inch and a half in diameter; and hence the operation of lithotomy is almost superseded by the more simple procedure of extracting the stone by dilatation.

The orifice of the urethra or *meatus urinarius* is situated above and in front of the entrance of the vagina, at the further end of the vestibulum, between the nymphæ, and anterior to the hymen in the virgin: it is placed at the distance of an inch from the clitoris. To the eye it presents the appearance of a closed circular aperture, slightly raised and thickened at its under edge, with a depression in its centre. Without ocular inspection, it may be found by carrying the fore finger below the clitoris, down along the symphysis pubis for a short distance, when it can be distinguished by its forming a soft semicircular projection, and its corresponding depression can be readily felt. Under examination with the finger the projection of the meatus increases as if by erection, and thus at once becomes more perceptible to the touch: the inferior lip of the meatus is continuous with the anterior mesian column of the vagina, and contains within it some large mucous crypts; this was formerly termed the corpus glandulosum. In order to avoid touching the clitoris, which, as a matter of delicacy, is of no slight importance, the meatus may be easily found without exposure, by carrying the finger into the vagina, along the anterior wall of which an elongated spongy swelling will be perceived; by advancing the finger along this swelling the meatus may be readily reached.

If the urethra be laid open, its mucous membrane is seen thrown into longitudinal plicæ, with valleculæ or depressions between them. Some of the plicæ are larger than the rest: there is usually one large fold along the posterior wall of the canal, and one on either side; the fold at the back part, after passing for a short distance, generally divides into two branches: it has been compared to the caput gallinaginis in the male. Besides these there are other folds, which, when the urethra is closed, dove-tail into corresponding depressions. The mucous membrane is of a rosy tint at the meatus, but becomes paler towards the bladder: it is copiously supplied with mucous follicles. These open generally in the depressions between the rugæ; but there are some large depressions or crypts, into which numerous smaller follicles open, situated just within the meatus: these equal in size the blunt end of and ordinary probe; they are imbedded in the under labium of the meatus, and, forming a considerable projection, constitute the *corpus glandulosum* of some authors. So also, in the vicinity of the commencement of the urethra, there is a collection of large lacunæ visible: indeed the under part of the mucous membrane is at this part studded with small orifices of mucous crypts. These are evidently different from the ordinary lacunæ of the urethra: the latter are analogous to those of the male canal, and, being situated between the longitudinal plicæ, open obliquely forwards. They are the seat of a copious mucous secretion.

The mucous membrane within the meatus is slightly depressed at its floor, which gives the urine a direction forwards and upwards. The whole canal is surrounded with a plexus of numerous small veins, mixed with a considerable quantity of elastic or contractile tissue (*the corpus spongiosum*); hence the female urethra possesses the undoubted attributes of an erectile structure.

Organization.—The organization of the female urethra is analogous to that of the male: it is essentially a mucous canal, belonging to the genito-urinary division of mucous membranes, and is composed of a mucous layer, covered externally by a layer of contractile tissue. The mucous layer is formed of the ordinary basement membrane, covered with a dense pavement epithelium, formed of broad, oval, and conical, compressed cells. External to this is a layer of that remarkable tissue described by Kölliker as entering so extensively into the structure of the male urethra, as well as all the other mucous outlets of the body; this is necessarily much more simple in its arrangement than the corresponding layer of the male urethra, and is continuous with some of the longitudinal muscular fibres of the bladder.

The *arteries* supplying the urethra are derived from the inferior vesicle, the uterine, and vaginal.

The *veins* terminate in the pudic or branches of the internal iliac.

The *lymphatics* terminate in the hypogastric ganglia.

* Guthrie on Diseases of the Bladder, &c., pp. 47, 48.

Its *nerves* arise from the pudic and the hypogastric plexus of the sympathetic.

Prostate gland of the female. — Has the female a prostate? Guthrie, in his work on "Diseases of the Bladder and Urethra," assigns a prostate to the female, which, according to him, has a form like that of the male prostate, and nearly a similar structure. He says it surrounds the commencement of the urethra. He further states it to be the size of the prostate of a boy before the age of puberty; and rather regards it as existing in a rudimentary form than as an organ possessing any follicular or glandular structure. He considers it as of use in giving the urethra support, and as affording a fixed point for the action of some of the muscular fibres of the bladder.

Guthrie quotes the authority of De Graaf, "De Mulierum Organis," in support of his opinion. "*Sed ulterius, inquiret aliquis, unde illi ductus sive lacunæ humorem illum hauriant? priores illæ scilicet, quocirca colli orificium et meatus urinarii exitum conspiciuntur ex parastatis mulierum seu potius crasso et membranoso corpore circumcirca meatum urinarium existente humorem suum accipiunt; posteriores vero ex nervoso-membranosâ colli uterini substantiâ liquorem suum colligunt.*"

De Graaf, however, refers to that mass of follicles surrounding the meatus and commencement of the urethra, rather than to any special organ worthy of the designation of *prostate*. Cowper also denominates the mass of follicles surrounding the meatus as the "*corpus glandulosum.*"

I confess that I have not been able to trace a prostate in connection with the female urethra: there is, however, generally found a firm mass around the canal, which is much thicker at the under part than at the upper, and to which I believe Mr. Guthrie refers. It is certainly not muscular; but it does not present evidences of glandular structure; containing merely a large quantity of areolar and elastic fibre. According to the notions of the homologies of the male and female now prevalent, the prostate should be represented in the female by a rudimentary structure in connection with the uterus rather than the urethra, inasmuch as it is essentially a sexual organ, and developed in the embryo from the *protometra*.

Pathology. — The female urethra is *wanting* where the entire uropoietic system is absent, as also when the bladder is deficient: it is also wanting in cases of ecrophy of the female bladder, and in cloacal formation.

In consequence of arrest of development, it may terminate in the vagina, or may receive the vagina or rectum at the posterior part.

Sometimes the urethra is abnormally dilated, as a congenital malformation.* This is rare: it is more frequently dilated after the removal of calculi, &c., from the bladder. Rare instances have been known in which the act of copulation has been performed through the urethra instead of the vagina.

Preternatural contractions of the urethra sometimes occur from pressure of the displaced uterus or the prolapsed vagina: they sometimes arise, as in the male, from inflammation, and constitute true stricture of the canal: this is exceedingly rare.

The urethra deviates from its normal direction in prolapsus of the bladder and uterus; — it takes on more or less of a serpentine direction; — this distortion of the canal not unfrequently gives rise to retention of urine. As the uterus enlarges during pregnancy the bladder is carried upwards, and, with it, the urethra is slightly raised.

The urethra may, however, be excessively dilated without incontinence of urine, of which an instance has come to my own knowledge. A woman of the town was admitted into the London Hospital, in consequence of retention of the menses: she had imperforate hymen; the urethra was enormously dilated, and no doubt she had admitted sexual intercourse through. She had no incontinence of urine.

Dr. Chamberlain also met with a case of imperforate hymen, where the urethra admitted the forefinger.* Dr. Oldham has observed the same in atresia vaginæ, unattended with incontinence of urine.

The urethra suffers a partial or total inversion, forming a tumour at the vulva, attended with difficulty and pain in voiding urine.

M. Sernin mentions the case of a girl eleven years of age, who experienced difficulty in making water. He examined her after a violent attack, and found a cylindrical body, four inches long, hanging from the vulva; and whenever she attempted to make water this projection swelled up. It was removed with success. It was presumed to be an inverted urethra.†

The female urethra is liable to injuries of various characters: the most common are simple contusions and lacerations, or it may be divided partially or completely by cutting instruments. The urethra frequently suffers contusion with the neck of the bladder in cases of protracted labour, from pressure of the child's head against the pubis. Under these circumstances sloughing often succeeds, and a fistulous communication between the urethral orifice of the bladder and vagina results, leading to incontinence of urine.

Lacerations of the female urethra are very uncommon, and require no particular observations; a simple retention of the parts by suture would be advisable to secure their re-union.

Simple incisions of the urethra, as in the operation of lithotomy, generally reunite successfully: this, however, is not invariably the result, and hence the occasional occurrence of incontinence of urine. The urethra, although extremely dilatable, is occasionally stretched beyond its natural capacity, in the removal of

* Rokitansky's Pathological Anatomy, vol. ii., Sydenham Society's edition.

* See also Portal, Cours d'Anat. Méd. vol. iii. p. 476.

† Recul. Period. tom. xvii. p. 304.

calculi or foreign bodies from the bladder, and thus becomes paralysed, and never afterwards recovers its normal tone. This is an unfortunate condition, as it admits of no remedy.

The female urethra is occasionally the seat of inflammation: this is almost invariably of the catarrhal form, and may arise spontaneously or as the consequence of gonorrhœa. The follicles at the meatus are especially liable to inflammation, in conjunction with the follicles of the vulva and margins of the nymphæ. The disease is described by Dr. Oldham under the head of the "Follicular Inflammation of the Vulva." It consists of a number of slightly raised vascular points, clustering around the elevated border of the orifice of the urethra, and skirting the margins of the nymphæ. The points are isolated and small; but, as the disease progresses, several of them coalesce, and here and there a minute speck of ulceration may be seen in their centre; but little or no swelling accompanies it.

Dr. Ashwell has recognised the same disease, and concludes that the same is alluded to by Dr. Churchill, where he speaks of "a more circumscribed inflammation which may attack any portion of the vulva, and is often seen merely surrounding the orifice of the urethra, and occasionally confined to the clitoris." *

Specific inflammation of the urethra is usually the consequence of gonorrhœa. The disease seldom attacks the female urethra until after the vagina has been some time affected. It is easily recognised by a swelling or pouting of the meatus; and on pressing upwards against the pubis the true gonorrhœal discharge appears. It is accompanied with a sense of scalding on micturition and pain; but the symptoms, for obvious reasons, are much milder than in gonorrhœa of the male. It is amenable to the same treatment.

Tumours of various kinds are occasionally found connected with the meatus and the urethra itself; the former have their seat especially in the inferior labium of the urethral orifice. The most common is the *simple vascular tumour*, first described by Morgagni as "a red fungous excrescence, the size of a bean, sometimes to be observed attached to the orifice of the urethra." It has since been recognised by others; and has been well described by Sir Charles M. Clarke. Sir C. Clarke describes it as a vascular tumour, arising from the meatus urinarius. "Its texture is seldom firm; it is of a florid scarlet colour, resembling arterial blood, and if violence is offered to it, blood of the same colour is effused. It is exquisitely tender to the touch, and if an accurate examination of it be made, it appears to shoot from the inside of the urethra. Its attachment is so slight that it appears like a detached body lying upon the parts." It is sometimes connected higher up with the urethra, and can then only be brought into view by introducing a catheter or probe, and separating forcibly the walls of the urethra, when it will be found attached to the mucous membrane.

* Ashwell, on the Diseases of Women.

Mr. Hughes, of Stroudwater, described a tumour "of a red colour, and of a soft, spongy texture, with an irregular, jagged surface, connected with the meatus." He removed the meatus, which completely included the disease.

Carcinomatous tumours are also met with in connection with this part. They have been described by Boivin and Dugès. They are frequently associated with similar diseases of the uterus. They are generally of the encephaloid character, present a lobulated appearance, and are exceedingly painful. If unaccompanied by disease of other organs, they can be successfully removed.

Fungoid tumours of the malignant class spring occasionally from the mucous membrane of the urethra. After excision they have a great tendency to recur. They are occasionally associated with a similar disease of the bladder.

The urethra sometimes becomes thickened along its whole extent. According to Clarke, this thickening exists principally in the cellular membrane surrounding the urethra, and is accompanied by a varicose state of the circumjacent veins. On examination, a bulbous tumour will be found behind the pubis, and if much pressure is made upon it, pain will be produced, but not of a severe kind."* It is accompanied with a mucous discharge from the urethra and vagina. The vessels on the surface of the tumour become so large as to admit of being opened with a lancet. When the patient is erect the size of the vessels increases, and they diminish in the recumbent position. Sometimes a pouch forms in the urethra, in which a few drops of urine are lodged: this can be emptied by pressure with the finger. The mucous membrane covering the tumour is sometimes thick, occasionally thin and shining. The disease occurs principally in married women who have had children; and, according to Clarke, in those with red or auburn hair and fair complexions. The disease seems to consist of an enlargement of the veins of the part, with hypertrophy of the cellular membrane.

The female urethra is rarely the seat of stricture. I have made inquiries of some of the most experienced accoucheurs in London, and they agree that stricture of the female urethra is very rare. The circumstance clearly depends on two causes; the first is the extreme natural dilatability of the urethra in women; and the second is, that, although it is liable to gonorrhœal inflammation, the disease does not persist long in the canal, and consequently its tissues are not involved in protracted chronic inflammation, as is so common in the male.

Sir Benjamin Brodie, however, met with a case of stricture in the female urethra: it commenced at the extremity of the canal,

* C. M. Clarke, on some of the Diseases of Females.

and extended half an inch back, and was so tight that it scarcely admitted the finest probe. My friend Curling also met with a case of stricture, attended with retention of urine. Being foiled in the introduction of the catheter, he was compelled to puncture the bladder in the direction of the canal beneath the pubis. The disease had arisen from the contusion to which the urethra had been subjected in a protracted labour, which had taken place twenty-eight years before. Since that time the woman had always experienced difficulty in making water, and had twice suffered retention, but no catheter could ever be passed. The aperture of the meatus was large, and there was great induration around: a small catheter was passed about an inch and a half, but could not be made to enter the bladder. The bladder was punctured, and between thirty and forty ounces of urine drawn off. The stricture was afterwards dilated with bougies.

COMPARATIVE ANATOMY.

The comparative anatomy of the urethra has been most carefully examined by Cuvier; and I have borrowed largely from his celebrated *Leçons d'Anatomie Comparée*, in my description.

Cuvier divides the urethra into two portions; the first extends from the orifice of the bladder to a short distance anterior to the prostate, whilst the second is continued thence to the orifice at the glans.

In the first portion of the canal in mammiferous animals generally,—that is, in what is termed in man the prostatic portion,—we find the verumontanum surrounded by prostatic ducts and terminations of vasa ejaculatoria; whilst in many the sinus prostaticus is of an enormous size: this is especially the case in the elephant.

In many animals we find temporary longitudinal folds of membrane: these are, however, permanent in some, as in the marmot: in this animal as many as twelve pass off on each side, and, enclosing small spaces, render the canal exceedingly irregular, and thus retard the flow of urine and semen.

With respect to the comparative length of this part of the canal there is great variety. Thus in man and the apes it is short, and surrounded by the prostate. In the *makis* it is long and slender; it is long in the *Cheiroptea;* and of medium length in the *bears*. In the *hedgehog* it is about one third the entire length; it is more than half in the *civet, cat, sarigue, kangaroo*, and *phascolome;* it scarcely reaches this length in the *giant kangaroo;* and is of less extent in the *dog*. It is actually longer, and its diameter is larger, in the *marmot;* scarcely half the length in the *rat* and *guinea-pig;* somewhat less than half in the *hare;* short, and not a quarter of the entire length in the *squirrel;* it is not more than a third or fourth in the *elephant, Pachydermata, Solidungula, Ruminants*, the *dolphin*, and *porpoise*. It is usually relatively shorter in *man* and the *apes* than in all other mammiferous animals; and it is amongst the *Carnivora*, in whom the penis is comparatively short, as the *cat* and *civet*, that it appears to bear the largest proportion to the other part of the canal. Cuvier denominates this pelvic part of the canal the *muscular* portion, because it is usually surrounded by a muscular layer. Thus in man and the apes this is especially remarkable on the sides of the prostate, where the levator ani and levator prostate are situated.

In the rest of the mammifera the muscular layer is circular. In the *Cheiroptera, mole, hedgehog*, and *cat*, it is remarkably thick; in the *dog, civet*, and *sarigue* it is thin; it is scarcely perceptible in the *marmot*, where there is scarcely any thing more than a tendinous covering. In the *Rodents* it is generally of moderate thickness; but in the *Pachydermata* and *Ruminants* it is of great thickness.

Cuvier suggests that the object of this muscular layer is to expel the urine and seminal secretion, by forcibly contracting the first portion of the urethra; and hence it is found so fully developed in those animals whose penis is long, as in the *Ruminants*, and in those in whom that organ is short, as in the *cat;* for in the first it is requisite to force the fluid along the lengthened penis, in the latter it becomes necessary to expel it beyond the limits of the penis. He says that this species of ejaculation is requisite, when any obstacle exists in the urethra, to the free discharge of semen, as is the case in the *porpoise* and the *dolphin*, where the membranous part of the urethra, being wholly surrounded by the prostate, forms an acute angle with the remainder of the canal, and becomes considerably contracted at that part. In these animals there is a thick muscle, attached behind to the front of the corpora cavernosa; the fibres of which, directed backwards, cover the prostate gland, and pass as far as the under part of the neck of the bladder. The office of this is necessarily to overcome the difficulty in the expulsion of the contents of the urethra, arising from the peculiarity just mentioned.

In many animals, as in the *Ruminants* and *Pachydermata*, the communication between the former part of the urethra and the second or spongy portion is by no means direct; but it takes place at the superior part of the latter by a sort of opening at a short distance from its commencement: this is the case also in the *wild boar*. The spongy portion begins under this condition in the form of a *cul-de-sac* of varied diameter,—a sort of bulb,—into which the semen is received after it has traversed the muscular portion of the urethra, whilst the secretion of Cowper's glands escapes into its sides. In other cases, as in the *squirrels* and *marmots*, this *cul-de-sac* receives only the orifices of these glands, and continues in the form of a short canal, which opens into the urethra either at the middle of the penis, or at a short distance beyond. The urethra in this instance passes over it, and they are both surrounded by the vascular tissue investing the bulb.

According to Owen, in the *kangaroo* the combined prostatic and membranous or muscular part of the urethra is proportionally longer and wider in the marsupial than in any other mammiferous quadrupeds. It swells out immediately beyond the neck of the bladder, and then gradually tapers to its junction with the spongy part of the urethra; it is not, however, divided like the vagina. Its walls are thick, formed of an external thin stratum of nearly transverse muscular fibres, and a thick glandular layer, the secretion of which exudes by innumerable pores upon the lining membrane of this part of the urethra.*

The urethra in the *Monotremata* approximates in many of its characters to that of the bird. "It begins by a small orifice at the root of the penis, near the termination of the pro-genital passage, and, by the action of certain muscles, it can be brought into closer approximation with the uro-genital passage." Owen supposes that this temporary continuation of the urethra and uro-genital passages takes place during the vigorous muscular and vascular actions of the parts in coitu, and that the semen is then propelled from one along the other without escaping into the common ventricular compartment of the cloaca "† According to Cuvier, in the *Gerboise* de Mauritanie the spongy portion of the urethra does not join the corpora cavernosa until it reaches the glans.

For the comparative anatomy of the urinary apparatus in birds, reptiles, and fish, see the separate articles on these subjects.

The urethra in the females of the lower animals offers no peculiarity worthy of notice.

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John Adams.

* See article Marsupialia.
† See article Monotremata.

URINE.

URINE. — Lat. *Urina;* Gr. *τὸ οὖρον;* French, *l'Urine;* Ital. *l'Urina;* Germ. *das Harns.*

The urine may be defined as that fluid which is eliminated by the kidneys in the discharge of their excretory function.

The human urine being that of an omnivorous feeder, differs materially from that which is excreted by animals purely carnivorous or herbivorous. In cases occasionally met with, however, where, either from congenital taste, want, or the indulgence of eccentricity or curiosity, vegetable food alone has been taken by human beings, the urine has been observed to undergo certain modifications as a consequence.

The urine, it is obvious, must vary much in constitution, according to the conditions under which the organism is placed, both in respect to external and internal circumstances. Thus the state of the atmosphere, as respects heat and cold, dryness and moisture, will affect the quantity of water excreted, as a constituent of the urine, while the quality and quantity of the ingesta, the state of the chylopoietic organs, and the amount of exertion to which the body has been subjected, are all causes tending to modify the amount, and perhaps also the nature and quality, of the solid matters excreted by the kidneys.

When treating, therefore, of the chemistry of normal urine, it must be borne in mind that, in fixing a standard, we are but giving a result more or less approaching to the truth, and that the real method of obtaining a philosophical view of its chemical constitution is, to regard the urine in its variations, in the hope of obtaining some fixed law whereon to base a knowledge of the peculiar influence of the several circumstances on which the variations depend.

The chemical analysis of this complex fluid was undertaken by Berzelius, who, with his accustomed accuracy, produced a result in which the various improvements and advances in chemistry have rendered it necessary to make but little change.

The number of constituents of healthy urine has been but little increased by discovery since Berzelius wrote, one or two only having to be added to his list.

It will be our object to enumerate these constituents, and describe such as may require especial notice, before proceeding to consider the quantitative analysis of the urine.

The following, then, may be regarded as a list of the constituents of healthy urine: —

Water.
Urea.
Extractive matters. { Of four kinds, differing in their reactions and solubility in menstrua.
Colouring matter. { Of two kinds, brown, (or *hæmaphæin*), and red (or *uroerythrin*).
Mucus.
Uric acid.
Hippuric acid.
Carbonic acid.
Lactic acid.
Sulphuric acid.
Hydrochloric acid.
Phosphoric acid.
Silicic acid.
Hydrofluoric acid.
Soda.
Potash.
Lime.
Magnesia.
Ammonia.
Oxide of iron.

Other acids, peculiar to urine, have been described by authors, but their qualities are not sufficiently determined to admit of their being yet classified as constituents.

Urea. — This constituent of the urine has been supposed by some to form during the evaporations necessary for its extraction. This, however, is not the case, as I have been able to obtain it by agitating the officinal rectified ether with urine in the natural state, and then allowing the ethereal solution, which separates above the urine, to evaporate spontaneously. The urea so obtained is free from lactic acid, showing that the view of MM. Cass and Henry, who consider urea to exist in urine in the form of lactate, is in all probability erroneous.

Urea possesses the following ultimate constitution: —

$$C2, \quad N2, \quad H4, \quad O2.$$

Its chemical properties are as follows: —

When heated on platinum foil it fuses, and on the heat being urged, it yields fumes of carbonate of ammonia. It is very soluble in both cold and warm water.

A concentrated solution of urea will bear a heat of 212° Fahr. without decomposition, but it quickly decomposes at that temperature when in dilute solution.

Alcohol of specific gravity 0·816 dissolves one-fifth of its weight of urea at 60° Fahr.; boiling alcohol dissolves nearly its own weight.

Urea is slightly soluble in ether.

The caustic alkalies boiled with urea decompose it into carbonate of ammonia.

The nitric and oxalic acids combine with urea, forming more or less insoluble salts, and on this fact the processes for the extraction of urea, from its combinations, chiefly depend.

Urea possesses neither an acid nor alkaline reaction. Its crystalline form is that of a four-sided prism.

Extractive matters of Urine. — There are four of these extractives; one soluble in alcohol as well as in water, and three soluble in water, and *not* in alcohol.

That which is soluble in alcohol may be obtained from the urine by digesting alcohol of specific gravity 0·833 on an extract of urine, and after crystallising the urea by means of nitric acid from the products of the alcoholic solution dissolved in water, separating the uncrystallisable matter, and neutralising it with carbonate of baryta: the mass must then be dried, and alcohol must be used to separate the extractive from the barytic salt.

Its chemical properties are as follow: —

When heated, it swells much, and leaves a copious alkaline carbonaceous mass.* It reddens litmus paper.

Neither bi-chloride of mercury, nor the acetate of lead, is capable of precipitating its watery solution.†

Both acid and alkaline solutions are incapable of effecting any precipitation of this extract from its solution in water.

Protochloride of tin, nitrate of silver, and di-acetate of lead, produce precipitates.

It may be well to mention, that if anhydrous alcohol be digested on this extractive, which has been called osmazome, it is capable of being divided into two portions; the one soluble and the other insoluble in that fluid.

The property of being precipitated by the di-acetate of lead, nitrate of silver, and protochloride of tin, belongs peculiarly to that part of the extractive matter which is soluble in anhydrous alcohol.

Animal extractive soluble in water only. — This may be procured by dissolving in water an extract of urine, which has been digested with alcohol of specific gravity 0·833. By the re-solution we separate any vesical mucus, lithic acid, earthy phosphate, or silica, which may be contained in the mass. The solution

* It contains an alkaline lactate.

† If these salts produce a precipitate, it is because alcohol has been used of higher specific gravity than 0·833.

is now precipitated with acetate of baryta, in order to rid it of sulphuric acid. The sulphate of baryta is collected on a filter, and the filtered liquor neutralised with ammonia, and then again thrown down with the acetate, which now causes a precipitate of phosphate of baryta.* This is to be collected, and the filtered liquor evaporated in order to drive off the ammonia; or, what is better, it may be neutralised by acetic acid. Neutral acetate of lead is now added to the solution, which causes a copious precipitate. This must be collected and washed, and then decomposed by sulphuretted hydrogen, which precipitates sulphuret of lead, and leaves the animal extractive in solution. This may be obtained by evaporation. This extractive is, however, but part of that meant to be understood as the "animal extractive soluble in water only," so often mentioned in analyses. The remainder of it may be procured by precipitating the liquor (in which the precipitate by neutral acetate of lead subsides), by means of the di-acetate of lead; then collecting the precipitate, decomposing it as before by sulphuretted hydrogen, and procuring the extractive from the clear liquor. It must be remembered that each of these extractives has peculiar properties, perhaps dependent on the processes used to obtain them. There is also a portion of animal extractive left unprecipitated by the di-acetate of lead. It is easily obtained from the liquor by ridding the solution of any lead which may exist in it by means of sulphuretted hydrogen, filtering, and then evaporating to dryness.

It is a mixture of these three peculiar extractives which constitutes the "animal extractive soluble in water only" of Berzelius.

The properties of the extractive matter precipitated by the neutral acetate of lead are as follows:—

It is of a brownish colour, translucid, and does not deliquesce; has no taste, and scarcely affects litmus paper.

Its solution is rendered cloudy by corrosive sublimate, and more so by the protochloride of tin.

The extractive precipitable by the di-acetate of lead has the following properties:—

It is of a yellowish brown colour; it has a slightly bitter taste, and does not deliquesce.

The watery solution of this extract is of a deep yellow colour.

It is not precipitable by the solution of bichloride of mercury; but the protochloride of tin, the di-acetate of lead, and nitrate of silver precipitate it of a dark brown colour.

The third extractive, which was precipitated neither by the acetate nor di-acetate of lead, possesses the following characters:—

It is of a yellow colour. Solutions of bichloride of mercury, protochloride of tin, and nitrate of silver precipitate its aqueous solution. The precipitate produced by the last of these re-agents is of a dirty yellowish red colour.*

Colouring matters. — These are two in number, Hæmaphæin or the brown; and Uroerythrin, or the red.

a. Hæmaphæin.—This is the substance which gives the yellow or brownish yellow tint to urine, and according to its proportion the urine assumes a lighter or deeper colour. According to Scharling, the odour also of the urine depends on this principle. It is soluble in alcohol, and the alcoholic solution reddens litmus. The odour, when concentrated, is said to resemble that of castor. Scharling believes this colouring matter to be an oxide of a radical, to which he has given the name of omichmyle.

β. Uroerythrin. — This exists but in very minute quantity in healthy urine; it attaches itself especially to the lithic acid, being precipitated with that principle on all occasions. It becomes abundant in some forms of disease.

Mucus. — For the history of this substance see article MUCUS.

Uric or lithic acid. — This acid may be procured from the urine by the addition of a few drops of strong hydrochloric acid, which, after the lapse of some hours, produces a reddish crystalline precipitate of lithic acid. This red colour is caused by an admixture of colouring matter of urine, for pure lithic acid is perfectly white. It may be obtained in a pure state from the red crystals by being dissolved in caustic potash, and then precipitated from its solution by the addition of hydrochloric acid. The precipitate may now be collected, and washed on a filter.

Lithic acid possesses the following chemical properties:—

It is insoluble in water.

It is easily soluble in a solution of caustic alkali, and precipitated from such solution by the addition of an acid.

It is dissolved by nitric acid with effervescence; and, by careful evaporation to dryness, yields a red or rather pink colour, which becomes of a fine violet tint when ammonia is dropped on it, or even when it is subjected to the action of strong ammoniacal fumes. This reaction of ammonia is very useful, inasmuch as it prevents the yellow stain which many animal matters produce with nitric acid from being mistaken for this reaction of lithic acid. In the former case, the ammonia increases the yellow tinge to an orange colour, which is very distinct from the beautiful violet tint of what is now known as murexid.

Before the blowpipe, this substance emits a fetid smell of burnt horn, mixed with an odour approaching to that of hydrocyanic acid.

The ultimate analysis of lithic acid shows its composition to be C 5, N 2, H 2, O 3.

Hippuric acid. — This acid is considered by Liebig to be constantly present in human urine.

* Both these precipitates produced by acetate of baryta contain animal matter, which, in the latter case, is in very considerable proportion.

* For further examination of these extractive matters, see the article by Berzelius, in his Traité de Chimie, vol. vii. p. 380.; Sur les Matières indéterminées dans l'Urine.

He states its quantity as equal to that of the lithic acid, in all persons feeding on a mixed diet. This, however, is certainly an over statement. It is present, but in small proportion, in healthy urine.

The ultimate composition of hippuric acid is as follows:—

C 18, H 9, N 1, O 6.

It crystallises in four-sided prisms, obliquely truncated.

When heated it gives out an odour resembling that of the tonquin bean.

Lactic acid.—The lactic acid was first discovered in the urine by Berzelius, who extracted it by the following process:—

A portion of urine was evaporated to dryness, and alcohol of specific gravity 0·833 boiled on the solid residuum.

The alcoholic solution was next evaporated, and the mass dissolved in water.

The watery solution was then boiled with a considerable quantity of hydrate of lime, till all ammoniacal fumes (from decomposing urea) were dissipated; the hydrate of lime now became coloured yellow, owing to the decomposition of animal matter.

The colourless solution was filtered, dried, and then treated with alcohol of specific gravity ·845. Equal parts of strong sulphuric acid and water were now added, guttatim, to the alcoholic solution, until sulphate of lime no longer precipitated; the clear liquor being decanted was next treated with carbonate of lead (recently precipitated), and was then filtered and evaporated to dryness.

The residue was treated with oxide of lead and a little water, by which means the lactic acid was converted into a sub-salt of considerable insolubility. This was collected, washed with water, and then decomposed by sulphuretted hydrogen. Thus, sulphuret of lead subsided, leaving the lactic acid free in the supernatant liquor, which, by evaporation, yielded it in the form of an acid yellow syrup, exceedingly deliquescent, and incapable of being thoroughly dried by heat.

Its chemical properties are the following:—

It gives out an acrid odour * when heated, and leaves a porous charcoal if the heat be continued. Alcohol dissolves it in all proportions. It is nearly insoluble in ether.

Its salts are all of a gummy and uncrystallisable nature, excepting the lactates of zinc and magnesia, which have been obtained in a crystalline form.

When lactic acid is added to a strong solution of the acetates of magnesia or oxide of zinc, the lactates of those bases are precipitated.

The existence of lactic acid, as a constituent of urine, has been denied by Liebig, and the question is as yet far from being satisfactorily settled.

The admission made of late by Liebig, however (as the result of his researches on muscle), that lactic acid exists in the juice of flesh, gives great probability to the correctness of Berzelius's statement.

* Not unlike that of the tartrates.

The other constituents of the urine which I have enumerated, require no particular notice in this place; and for the methods of quantitatively examining the fluid, I must refer to the article ORGANIC ANALYSIS, contained in this work.

Healthy urine possesses the following physical characters:—It is of a pale straw colour, limpid and acid; after standing some hours, it deposits a light, flocculent sediment, composed of mucus. This mucus, as it exists in health, suspended in the urine, does not materially interfere with the transparency of the fluid. The odour of urine is peculiar, and subject to modification from the use of various articles of diet, and remedies. Its specific gravity varies, owing principally to two causes—the condition of the atmosphere, as affecting the proportion of water exhaled by the skin, and the quantity and quality of the ingesta taken.

Healthy urine may, under these considerations, be said to vary in specific gravity from 1004 to 1032; while perhaps, under ordinary or average conditions of diet, temperature, &c., we may place its specific gravity at 1015 to 1022.

Quantitative composition of healthy Urine.—The quantitative composition of urine must of course vary considerably, owing to the conditions noticed above, as affecting its specific gravity. The following is the result of an analysis made on 1000 parts by Berzelius, on a specimen considered as healthy:—

Water	933·0
Urea	30·10
Free lactic acid; Lactate of ammonia; Extractive matters (alcoholic and watery)	17·14
Lithic acid	1·00
Vesical mucus	0·32
Sulphate of potassa	3·71
Sulphate of soda	3·16
Phosphate of soda	2·94
Superphosphate of ammonia	1·65
Chloride of sodium	4·45
Chloride of ammonium	1·50
Phosphate of lime and magnesia	1·00
Silicic acid	0·03

Dr. Bence Jones has experimented very carefully on the acidity of urine in health. His results show that the amount of acidity is always varying. Thus the urine passed longest after food was generally the most acid, and that voided while digestion was going on, much less so, and in some cases even alkaline, though the patient was in perfect health. These conditions pertained, whether a pure vegetable or animal diet was taken. In the case of a pure vegetable diet, however, the decrease in acidity, after taking food, was not so marked as when a pure animal diet was observed; the urine in the latter case sometimes becoming highly alkaline, but in the former never exceeding neutrality.

Other analyses of more recent date have

been published by the following observers, viz. Marchand, Simon, Becquerel, Lehmann, &c. I shall quote several of these from the work of Franz Simon, which has been excellently translated into English by Dr. Day, for the Sydenham Society.

Simon analysed two specimens of the urine of a healthy man, 33 years of age. He was of sanguineous temperament. The specific gravity was in the first case 1011, and in the second 1012.

1000 parts yielded —

	1st.		2nd.
Water - - -	963·20	-	956·00
Urea - - -	12·46	-	14·578
Uric acid - -	0·52	-	0·710
Alcoholic extractive, free lactic acid -	5·10	Extractives and ammoniacal salts.	4·800
Spirituous extractive	2·60		5·590
Extractive, soluble in water only, and vesical mucus - -	1·00		2·550
Lactate of ammonia	1·03		
Chloride of ammonium - - -	0·41		
Chloride of sodium -	5 20	-	7·280
Sulphate of potassa -	3·00	-	3·508
Phosphate of soda -	2·41	-	2·330
Phosphates of lime and magnesia -	0·58	-	0·654
Silicic acid - -	a trace	-	a trace.

The urine of the same individual was also examined under three varying conditions, as follow: — A, on rising in the morning, several glasses of water having been drunk the previous evening; B, water and some coffee taken, and violent exercise had recourse to during two hours, pulse 100, with occasional intermissions; C, urine voided half an hour after urine B. These urines were all acid; C most so, and B the least. All three specimens were clear, and B the least coloured.

The following is the result of the analyses:

	A.	B.	C.
Water - -	972·600	981·000	957·600
Urea - -	8·402	7·568	15·257
Uric acid, extractives, and ammoniacal salts and chlorides - -	13·960	8·618	19·140
Phosphate of soda	1·850	1·250	2·750
Sulphate of potassa - -	2·790	2·200	5·000
Phosphates of lime and magnesia - -	0·479	0·264	0·656

The specific gravities of the above specimens were respectively 1010, 1008, and 1014.

Lehmann has analysed the urine collected during 24 hours, from a well-fed and healthy young man. The following three results were thus obtained by him: —

	1.	2.	3.
Water - -	937·682	934·002	932·019
Urea - -	31·450	32·914	32·909
Lithic acid -	1·021	1·073	1·098
Lactic acid -	1·496	1·551	1·513
Aqueous extractive -	0·621	0·591	0·632
Spirituous and alcoholic extractives -	10·059	9·871	10·872
Lactates -	1·897	1·066	1·732
Chlorides of sodium and ammonium -	3·646	3·602	3·712
Alkaline sulphates -	7·314	7·289	7·321
Phosphate of soda - -	3·765	3·666	3·989
Phosphates of lime and magnesia - -	1·132	1·187	1·108
Mucus - -	0·112	0·101	0·110

The specific gravities of the urines which yielded these above analyses, judging from the amount of solid content, must have been as high as from 1022 to 1029. This is very high, indeed, as an average of 24 hours.

The mean composition of urine is stated by Becquerel as follows: —

		Mean from four healthy Men.	Mean from four healthy Women.
Specific gravity	-	1018·9	1015·12
Water - -	-	968·815	975·052
Solid matters -	-	31·185	24·948
Urea - -	-	13·838	10·366
Uric acid -	-	0·391	0.406
Fixed salts -	-	7·695	6·143
Organic matters	-	9·261	8·033

Simon very properly remarks on the above analyses, that the discrepancies to be observed in the composition of the urine, principally depend on the variation in the proportion of water; and that if we consider the proportion of each *solid* constituent to the whole amount of solid matters, the differences will not appear nearly so great.

The variations caused in the urine by the ingestion of various mineral substances, and of organic compounds taken either as food or medicine, have attracted the attention of several chemists of eminence. Liebig has theorised freely on this subject, and it is but right that what he has published should be copied into this article, if only as part of the history of the urine, while I would warn the reader carefully to separate in his mind the matters of fact from the theoretical part of the subject, inasmuch as a great deal yet remains to be done. The position of the inquiry is indeed at present such, that further advances may very probably lead us to detect the fallacy of theories which, it is to be feared, the present state of our knowledge may permit us to see in too attractive a form.

Liebig remarks, "When the hydrochloric acid (in the stomach) has exercised its solvent action upon the aliments, and the latter have passed into a state of solution, the soda which originally entered the organism in combination with the hydrochloric acid, that is, as common salt, rejoins the hydrochloric acid during the preparation of the chyme, and previous to its transformation into chyle, the soda and the hydrochloric acid thus reunited combine again and form common salt: chyle and lymph have no longer any acid reaction, but, on the contrary, they manifest alkaline properties."* The alkaline reaction of the lymph, chyle, and blood of man and of the carnivorous animals cannot be owing to the presence of a free alkali, as is evident from the preceding observations; for the nutriments of man and of the carnivorous, as well as the graminivorous, animals, contain no free alkali, nor any salt formed of an alkaline base and an acid which might be destroyed in the organism by the vital process, and thus cause the alkaline base to be liberated. The blood must contain the same salts as exist in the aliments. With the exception of common salt, nothing is added during the digestion of the aliments. We have seen that this substance undergoes decomposition in the upper part of the digestive apparatus, being resolved into free soda and free hydrochloric acid; but we have also seen that the liberated soda rejoins the hydrochloric acid during the preparation of the chyme, and previous to the transformation of the latter into chyle; that is, when the acid has performed its function, viz. the solution of the aliments, — the salt formed by this combination, that is, common salt, has neither an acid nor an alkaline reaction. The salts with alkaline reaction contained in meat, flour, or grain, are alkaline phosphates. It is obvious that the alkaline reaction of the chyle, lymph, and blood of animals feeding upon animal and vegetable substances can only be derived from their alkaline phosphates. The serum of the blood can only be considered as a combination of albumen with an alkaline phosphate; the fibrin of the blood, or the fibrin of the muscular fibre, is a combination of albumen with phosphate of lime.

"The bibasic phosphates of soda and of potash are in many respects highly remarkable salts. Although of a tolerably strong alkaline reaction, yet they exercise no destructive action upon the skin, nor upon organic formations. They possess all the properties of the free alkalies, without being such: thus, for instance, they absorb a large amount of carbonic acid, and this in such a manner that acids produce effervescence in a saturated solution of this kind, just as they would in alkaline carbonates. They dissolve coagulated curd of milk or cheese, as well as coagulated albumen, into clear fluids with the greatest facility, just as caustic or carbonated alkalies do. But of still greater importance in relation to the secretion of urine is their deportment towards hippuric acid and uric acid. Hippuric acid dissolves with the greatest facility in water to which common phosphate of soda has been added. Uric acid possesses the same property at a high temperature; the phosphate of soda, in this process, loses its alkaline reaction completely upon the addition of uric acid and hippuric acid, and assumes an acid reaction. The acid nature of the urine of man, and of the carnivorous and graminivorous animals, is thus explained in a very simple manner.

"There are but two principal channels through which the salts entering the organism with the aliments can effect their exit from the body, viz. they must either be carried off in the fæces, or in the urine. The most simple experiments show that soluble salts are carried off by the fæces only when the amount of salt contained in the fluids in the intestines is larger than that contained in the blood. If the amount of salt in these fluids is equal or inferior to that of the blood, the soluble salts are re-absorbed by the absorbing vessels of the intestinal tube, and enter the circulation, and are then removed from the body by the urinary organs and channels. If the amount of salt contained in the intestinal tube is larger than that contained in the blood, the salts exercise a purgative action.

"If, after previous evacuation of the rectum, a weak solution of common salt (one part of salt to sixty parts of water) be taken by means of a clyster, no second evacuation will take place: the fluid is absorbed, and all the salt is found in the urine. This experiment yields the most convincing results if ferrocyanide of potassium is substituted for common salt. In this case the first urine excreted after the injection of the saline solution, and frequently even after so short a time as fifteen minutes, contains so copious an amount of ferrocyanide of potassium as to yield, upon the addition of persalts of iron, a copious precipitate of Prussian blue.

"The influence which salts in general exercise upon the secretion of urine is in the highest degree worthy of attention. It is a well known fact, that a very speedy emission of urine takes place in healthy individuals after drinking fresh pump-water. If ten glasses of water of from six to eight ounces each, containing no more than $\frac{1}{500}$th of its amount in salts, be drunk at short intervals, an emission of urine of the usual colour will, after the lapse of about ten minutes, follow the second glass, and from eight to nine evacuations of urine will generally occur in the course of an hour and a half. The urine in this experiment emitted in the last evacuation will be clear and colourless like pump-water, and the amount of salts it contains is little more than is contained in pump-water. There are individuals who are capable of thus imbibing from six to eight quarts of water consecutively without any inconvenience!!

* Lancet, 1844.

"But the case is quite different with water possessing an amount of salts equal to that of the blood; if even as little as 1-100th part of common salt be added to pump-water, and from three to four glasses drank, no evacuation of urine will take place, even two hours after drinking. It is almost impossible to drink more than three glasses of this saline water, for it weighs heavily on the stomach, as if the absorbent vessels had no power of taking it up. This obviously arises from the fluid within the channels of circulation, *i. e.* the blood, and the fluid without these vessels, *i. e.* the saline water, not exercising any physical action upon one another, *i. e.* not intermixing by endosmose or exosmose.

"Water containing a larger amount of salts than the blood, such as common sea-water, for instance, and even the weaker kinds of saline mineral waters, exercise again a different action from that of pump-water mixed with 1-100th of common salt; not only no emission of urine takes place after the imbibition of such saline water, but water exudes from the circulating vessels into the intestinal tube, and, together with the saline solution, is carried off through the rectum; purgation takes place, attended with much thirst, if the saline solution be in some measure concentrated.

"Considering that a certain amount of salts is absolutely necessary to constitute normal blood, we may deduce from these observations and experiments (which any one may easily imitate and verify upon his own person) that the physical condition of the tissues or of the bloodvessels opposes an obstacle to any increase or decrease of the amount of salts in the blood; and thus that the blood cannot become richer or poorer in salts beyond a certain limit.

"Fluids containing a larger amount of salts than the blood remain unabsorbed, and leave the organism through the rectum; fluids containing a smaller amount of salts than the blood enter into the circulation, absorb, and remove from the organism, through the urinary channels, all the soluble salts and other substances which do not belong to the constitution of the blood; so that, finally, only those substances remain in the organism which exist in chemical combination with the constituents of the blood, and which, therefore, are incapable of being excreted by the healthy kidneys.

"I have convinced myself, by careful and minute examinations, that urine emitted after drinking a copious amount of water invariably contains a somewhat larger amount of salts than the water which has been drank; whilst the amount of phosphates contained in the last emitted portions of the urine is extremely minute, and no longer detectable by the ordinary tests. It is, therefore, obvious that all the salts, without exception, contained in the urine, are to be considered as accidental constituents of the blood, which are excreted and removed from the organism precisely because they no longer form part of the normal constitution of the blood. The phosphates emitted with the urine were, previously, constituent substances which have been decomposed in the vital processes, or they existed as constituents of the blood, but upon its transformation into living tissues they were not admitted into their composition, they were not required in the constitution of the latter.

"Now, among the products of the vital processes, which, together with the soluble phosphates, are removed from the organism through the urinary organs and channels, there are two organic acids, namely, *uric* acid and *hippuric* acid, both possessing the property of combining with the soda or potass of the alkaline phosphates, and acquiring in the combination a higher degree of solubility than they possess, *per se*, at the common temperature of the body. It is obvious that, by the accession of these two acids, and by their action upon the phosphates of soda, an urate and hippurate of soda must be formed on the one hand, and an acid phosphate of soda on the other; and that, consequently, the urine must acquire an acid reaction.

"But the presence of these two acids in the urine is not the only cause of its acid nature; there exists another cause, which tends powerfully to maintain and increase it.

"According to the preceding remarks we ought to find in the urine all the soluble salts of the food, as well as a small amount of the phosphate of lime, which is soluble to a certain extent in acid fluids, together with magnesia. The amount of these latter substances will be in proportion to their solubility in acid phosphate of soda. The other insoluble salts of the aliments we ought to find in the fæces. In other words, assuming that the materials composing the aliments become converted into oxygen compounds, that is, are *burnt* in the organism, we ought to find in the urine all the soluble salts of their ashes, and in the fæces all the insoluble salts. Now, upon comparing the constitution of the ashes of the blood or of the aliments, or, rather, the salts contained therein, with those contained in the urine, we find that there exists a striking difference between their respective amounts of *sulphates*.

"According to the analyses of the ashes of the grains of wheat and rye*, the urine of an individual feeding exclusively upon bread ought not to contain a single trace of a sulphate, whilst the urine of an animal fed upon peas or beans ought to contain sulphates together with phosphates, in the proportion of nine of the former to sixty of the latter. Finally, as flesh contains no soluble alkaline sulphate (broth does not yield any precipitate of sulphate of barytes when tested with salts of barytes), the urine of carnivorous animals ought to be equally free from soluble sulphates. We find, on the contrary, that the urine of man, according to the most correct analyses, contains a far larger proportion of sulphates than the aliments partaken of; nay, even that the amount of the sulphuric acid

* Ann. der Chemie, Bd. xlvi. S. 79.

received into the system must, in many cases, be equal or superior to that of the phosphoric acid contained in the aliments. According to the analysis of human urine made by Berzelius and Lehmann, the amount of the sulphates present in urine is nearly double that of all the soluble phosphates together. Hieronymi found the amount of sulphate of potass contained in the urine of the tiger, the lion, and the leopard, compared with that of the phosphates, to be as 1 to $7\frac{1}{2}$. It can be distinctly and positively proved that these salts have not been partaken of in such proportions. But we now know the origin of the greatest portion of the sulphuric acid contained in the urine; this acid has entered the organism with the food, not in the form of a sulphate, but as *sulphur*.

" Gluten*, vegetable casein, flesh, albumen, fibrin, and the cartilages and bones, contain sulphur in a form quite different from the oxygen compounds of this substance. This sulphur is separated as sulphuretted hydrogen during the putrefaction of these substances; it combines with the alkalies, operating upon these animal substances, and may be obtained from such combinations in the form of sulphuretted hydrogen by means of stronger acids.

" Now, we know from the experiments of Wöhler, that the soluble sulphurets become oxidised in the organism; and that thus, for instance, sulphuret of potassium becomes converted into sulphate of potass; and it is therefore unquestionable that the sulphur of the constituents of the blood, derived from the aliments, or, what comes to the same point, the sulphur of the transformed tissues becomes finally converted into sulphuric acid by the oxygen absorbed in the process of respiration, and thus that in the urine it must appear in the form of sulphates; and from this cause the original amount of these salts contained in the aliments becomes increased. The alkaline base which we find in the urine, in combination with this sulphuric acid, is supplied by the soluble alkaline phosphates; and the latter, in consequence of the loss of part of this base, are converted into acid salts.

" By these considerations and views respecting the cause of the acid reaction of urine, I have been induced to prepare an artificial urine, which possesses the properties of natural urine, even although sulphuric acid be altogether excluded.

" If 40 grains of dry phosphate of soda (or 90 grains of the crystallised salt, $PO_5\ 2\left\{\begin{matrix}NaO\\HO\end{matrix}\right. + 24\ Aq.$) be dissolved in one pound of water, a fluid will be obtained having an alkaline reaction; if to this fluid we add 15 grains of uric acid, and 15 grains of hippuric acid, and the mixture is heated, both acids will completely dissolve, imparting a strong acid reaction to the fluid. The solution thus prepared does not deposit a trace of uric acid at a temperature from 37° to 38° (= 98°, 100° Fahrenheit = the heat of the blood); nay, it is even only several hours after complete refrigeration that a sediment is formed, consisting of uric acid containing soda: this sediment is of an analogous form to that deposited by natural urine after standing at rest for a long time. Upon collecting this sediment, in one of my experiments, after the lapse of twenty-four hours, I found that it weighed $7\frac{1}{2}$ grains, so that there remained still in solution $22\frac{1}{2}$ grains of the organic acids. Dilute mineral acids produce immediately, in the fluids filtered off from the sediment, a precipitate of uric acid.

" Proust, Prout, and all the other chemists who examined the urine previous to, or about the same period as, Berzelius, ascribed its acid reaction to the uric acid or phosphoric acid; hippuric acid was not known as a constant attendant upon uric acid.

" It follows, from all we have hitherto stated, that the acid nature of the urine of carnivorous animals, as well as that of man, depends upon the nature of the *bases* partaken of in the aliments, and upon the particular form of their combinations. In the flesh, blood, and other parts of animals, as well as in the grains of the cereal and leguminous plants, there exists no free alkali. The alkali which these substances contain is invariably combined with phosphoric acid; the acids formed in the organism by the vital process, namely, sulphuric acid, hippuric acid, and uric acid, share the alkali amongst them; and this, of course, must give rise to the liberation of a certain amount of phosphoric acid, or, what comes to the same point, to the formation of a certain amount of acid phosphates of soda, lime, and magnesia. The proportional amount of the liberated phosphoric acid varies with the temperature; at a higher temperature the phosphate of soda dissolves a larger amount of uric acid and hippuric acid than at a lower temperature — at from 37° to 38° more than at 15°. It is owing to this that urine, upon refrigeration, sometimes deposits uric acid, or urate of soda in a crystalline state, which, of course, can only take place by the uric acid, at a lower temperature, restoring to the phosphoric acid the soda or potass which, at a higher temperature, it had withdrawn from it. At the common temperature phosphoric acid decomposes urate of soda, whilst, at a higher temperature, uric acid decomposes phosphate of soda. When urine, containing uric acid, and manifesting an acid reaction, forms no sediment upon cooling, it shows that the amount of the phosphoric acid and that of the uric acid exactly balance each other with regard to their affinity for soda. Had there been present a larger proportion of uric acid, this would have separated upon cooling; whilst, on the other hand, the presence of a preponderating proportion of phosphoric acid would

* Dietrich (in the laboratory of Giessen) has examined gluten with regard to its amount of sulphur; he found wheat-gluten to contain from 0·033 per cent. to 0·035 per cent. of sulphur, exactly the same proportion as is contained in albumen or fibrin.

likewise have caused the precipitation of uric acid, because the affinity of the former for soda would then exceed that of the latter. This explains the circumstance that urine, in certain states, when from some cause or other its amount of sulphuric, hippuric, or other acid, becomes increased, precipitates a larger proportion of uric acid than urine in its normal state. The solubility of uric acid in urine must decrease in proportion as the amount of the other acids present in the urine increases, because those acids share the soda with the uric acid; and, of course, the larger the amount of soda which combines with these other acids, the less comes to the share of the uric acid. It is likewise owing to this, that uric acid very frequently precipitates from urine upon the addition of mineral or other acids, and that urine of a turbid, whey-like appearance, from the presence of uric acid, frequently manifests a far more strongly acid reaction than normal urine.

"Now, bearing in mind that the use of alkaline citrate (Gilbert Blane), of neutral paratartrate of potass, bi-tartrate of potass, tartarised soda, acetates of potass and soda, and tartarised borax, renders the urine alkaline by creating in it an amount of carbonated alkali; and that, likewise, after the eating of fruit, such as cherries, strawberries, &c., the urine is of an alkaline nature, inasmuch as these fruits contain alkalies combined with vegetable acids, it is obvious that the acid reaction of healthy urine is purely accidental, and that urine of an alkaline or neutral reaction cannot be considered as a symptom of a diseased condition of the body. All vegetable aliments, without exception, — tubers, roots and leaves, potatoes, turnips, greens, &c., — contain alkalies in combination with vegetable acids; potatoes, for instance, contain alkaline citrates; turnips, alkaline racemates and oxalates, &c. All these plants yield, upon incineration, more or less strongly alkaline ashes, the bases of which were contained in the living plants, as salts of vegetable acids.

"It is obvious that by adding these vegetables to a meat diet, to bread and to other aliments prepared from flour, the nature of the urine must become thoroughly altered; for the alkalies which these vegetables contain in combination with vegetable acids, enter the urine in the form of carbonated alkalies, and neutralise the acids, of whatever kind, which may be present. When partaken of in a certain proportion, they render the urine neutral; when partaken of in a larger proportion, they impart to it an alkaline reaction.

"The urine of all animals feeding upon vegetables, such as grass, herbs, roots, &c., has an alkaline reaction. The urine of the horse, of the cow, of the sheep, of the camel, of the rabbit, of the guinea-pig, of the ass, &c. is alkaline; it contains alkaline carbonates, and acids produce in it a lively effervescence.

"The acid, neutral, or alkaline reaction of the urine of healthy individuals does not depend upon any difference in the processes of digestion, respiration, or secretion, in the various classes of animals, but upon the constitution of the aliments, and upon the alkaline bases which enter the organism through the medium of these aliments. If the amount of these bases is sufficiently large to neutralise the acids formed in the organism, or supplied by the aliments, the urine is neutral; whilst it manifests an alkaline reaction when the amount of alkaline bases thus supplied to the organism is more than sufficient to neutralise the acids; but in all these cases the urine accords with the nature of the aliments taken.

"The inorganic bases and acids contained in the urine were, with the exception of sulphuric acid, which joins them in the organism, constituents of the aliments. The amount of inorganic bases and acids emitted through the urine in twenty-four hours must, in adult individuals, be equal to that of these bases and acids supplied to the organism, during the same period, through the medium of the aliments.

"From these data it follows necessarily, first, that the analysis of urine when made without respect to the inorganic salts, acids, and bases, supplied by the aliments, teaches nothing whatever, and by no means justifies us in drawing therefrom any physiological or pathological inference; secondly, that from the nature of the ashes of the aliments we are able to determine, positively, the constituents of the urine emitted; and thirdly, that only when these latter have been distinctly ascertained, can we expect to derive, from the analysis of the urine, any correct information with respect to the inorganic matters which have come to be present in it through processes of disease; this, at least, is the *chemical method* of quantitative investigation.

"Bearing in mind that the urine contains the soluble constituents of the ashes of the aliments, whilst the fæces contain the insoluble part of these constituents, we may form an accurate knowledge of both, at once determine in which urine soluble alkaline phosphates must be present, and in which they cannot exist. The ashes of all seeds, and of flesh and blood, contain a certain amount of soluble and insoluble phosphates, whilst the ashes of vegetables contain no free alkaline phosphate, but only insoluble phosphates. These vegetable ashes contain far more lime and magnesia than is required for the neutralisation of the phosphoric acid present. Hence, upon incinerating a plant, together with its seed, and lixiviating the ashes, we find no alkaline phosphate in the fluid obtained, although the lixivium of the ashes of the seeds, when incinerated and lixiviated by themselves, yields a considerable amount of these phosphates: the excess of lime and magnesia contained in the leaves and the straw enter here into combination with the phosphoric acid of the soluble alkaline phosphates, forming an insoluble compound.

"It will now be understood why the alkaline phosphates are generally absent from the urine of herbivorous animals, and also why, in certain cases, they may be found in the urine of these animals. If the nutriment of these animals contains no soluble phosphates, their urine cannot contain any; whilst, if we add a certain proportion of grain to their food, the alkaline phosphates may be detected in their urine. Thus it is obvious, likewise, that the soluble phosphates in the urine of man are merely accidental constituents, and that by simply adding lime or magnesia to the aliments, and thus assimilating the constitution of these aliments to that of the food of herbivorous animals, the urine must become altered in its nature and properties. The knowledge of the influence which alkalies, magnesia, and lime, or acids, exercise upon the properties of the urine, or, in other words, upon the secretory process of the kidneys, in the healthy organism, is of the highest importance for the curing of diseases.

"I believe that there is now required only a small number of good and correct observations to establish a fixed rule for the remedies necessary in various cases. Future properly-directed experiments will prove whether sanguification is absolutely dependent upon the presence of alkaline phosphates or not; we shall be able to determine whether weak solutions of alkaline phosphates are not the best solvents for uric acid deposited in the bladder; and likewise what is the influence which aliments rich in sulphur, such as mustard, for instance, exercise upon the separation of uric acid in the bladder, in consequence of the formation of sulphuric acid. At any rate, we may, by a judiciously-selected diet, alter with positive certainty, and at pleasure, the nature of the urine; we may, without causing any injury to health, keep it alkaline for a long time, by adopting a vegetable diet; and this is certainly the first condition necessary to insure the entire prevention of the formation of uric acid, as is the case with the herbivorous animals. By its combination with an alkaline base, uric acid must in the organism resolve itself into its ultimate oxygen compounds with the same facility as other organic acids, if the physician prohibits all substances to be taken as food which, like wine or fat, take possession of the oxygen necessary for the transformation of uric acid into carbonic acid and urea.

"The carbonated alkali in the urine of herbivorous animals is separated from the blood by the kidneys; the urine derives it from the blood; it is certain, therefore, if we examine the blood one hour or a few hours after the animal has partaken of food, we must find in it this alkali in the same state as it is found in the urine, and that at other periods of the day the ashes of the blood may not contain the least trace of free alkali. But the free alkali does not co-operate in the vital process in the animal organism; or, if it *is* necessary in this process, the part which it has to perform may be undertaken with the very same effect by the bibasic and tribasic alkaline phosphates.

"In like manner, when we are contemplating the presence of hydrochloric acid in the gastric juice, we must remember that the alkaline bases, soda, potass, lime, magnesia, are present in the aliments whilst in their natural state, invariably in the form of salts; that is, in combination with phosphoric acid, or with organic acids. When, therefore, in the digestive process, hydrochloric acid is supplied by the gastric juice, the first action of this acid is confined to the decomposition of these salts; the hydrochloric acid withdraws lime from the phosphate of lime; potass, or soda, chloride of calcium, or chloride of sodium or potassium, is formed on the one hand, and acid phosphate of soda or potass, or acid phosphate of lime, on the other; or acetic acid, paratartaric acid, or citric acid, are liberated by the decomposition of the salts of these vegetable acids contained in the aliments. At a certain stage of digestion the chyme will, according to the nature of the food partaken of, contain acid phosphates or free vegetable acids; and it is only upon the supply of gastric juice continuing, that thus, upon the amount of the hydrochloric acid increasing, we may detect, by analysis, free hydrochloric acid in the chyme: the gastric juice taken from an empty stomach contains invariably free hydrochloric acid, or acid phosphates."

Lehmann has made some very interesting observations, published in the "Journal für Praktische Chemie," by which he has shown the effects of diet on his own urine. He first observed the results produced by his ordinary diet during thirteen days, and found that the urea amounted on an average to about 46 per cent. of the whole of the solid matter excreted. The average quantity of urea excreted during the 24 hours amounted to about 500 grains.

During six days, on an ordinary diet, the uric acid excreted averaged about 1·089 parts per 1000, and the amount excreted during the 24 hours was about 18 grains.

On a purely animal diet, Lehmann found the amount of solid matters discharged in the urine during the 24 hours was much increased. The urine became pale in colour and strongly acid. On the addition of nitric acid, crystals of nitrate of urea were immediately formed, and uric acid was deposited in large crystals.

By careful analysis, however, Lehmann determined, that though a purely animal diet increases the proportion of urea excreted during the 24 hours, the amount of uric acid is not by any means materially influenced.

The earthy phosphates were discharged in large quantities under a purely animal diet, rising to about three and a quarter times as much as when ordinary mixed diet was taken.

With respect to the effects of a vegetable diet, Lehmann observed the urine to become of a darker colour than natural, and to remain of an acid reaction much longer than ordinary human urine. The following tables of comparison have been constructed by Franz Simon from the results of Lehmann: they possess a high physiological value.

	On mixed Diet.	On animal Food.	On vegetable Food.
	grammes.*	grammes.	grammes.
Amount of urine in 24 hours - -	1057·8	1202·5	909·
Specific gravity	1022·	1027·1	1027·5
Solid residue from 1000 parts of urine	65·82	75·48	66·41
Solid matter passed in 24 hours - -	67·82	87·44	59·23

	In 100 Parts of solid Residue.	Daily Amount in Grammes.
Urea during a mixed diet	46·230	32·498
Urea during an animal diet - -	61·297	53·198
Urea during a vegetable diet - -	39·086	22·481

	In 100 Parts of solid Residue.	Daily Amount in Grammes.
Uric acid during a mixed diet - -	1·710	1·183
Uric acid during an animal diet - -	1·674	1·478
Uric acid during a vegetable diet -	1·737	1·021

From the above it would appear, that the amount of urea is always diminished by a vegetable diet, while the proportion of uric acid excreted is not materially affected. Lehmann ascertained also, by other experiments, that the amount of lactic acid, phosphates, and lactates was scarcely changed, whether the subject of experiment lived on an animal, or vegetable, or a mixed diet. A vegetable diet was found to increase considerably the daily discharge of extractive matters; while far less was passed under an animal diet than when either a mixed or vegetable diet was used.

The following table, containing the results of Lehmann on different forms of diet, as affecting the daily amount of the various solid matters discharged by the urine, is a very important addition to our knowledge of this subject: —

	Mixed Diet.	Animal Diet.	Vegetable Diet.	Non-nitrogenous Diet.
	gramm.	gramm.	gramm.	gramm.
Solid constituents	67·82	87·44	59·24	41·68
Urea - -	32·50	53·20	22·48	15·41
Uric acid -	1·18	1·48	1·02	0 73
Lactic acid and lactates -	2·72	2·17	2·68	5·82
Extractive matters - -	10·49	5·20	16·50	11·85

* The gramme is equal to 15·4 grains troy.

Severe and continued bodily exercise was found by Lehmann to increase the discharge of urea, lactic acid, phosphates, and sulphates. He observed a diminution, however, in the proportion of uric acid and extractives discharged under the same conditions.

Simon, simultaneously with Lehmann, ascertained that the amount of urea, sulphates, and phosphates excreted, is increased by strong bodily exercise. Simon remarks upon this result: — "Further confirmation of the above observation is certainly desirable. If, however, we might assume it as a general fact, it would be an additional argument in favour of my view regarding the formation of urea; for it would then become still clearer that the urea is not formed during the change which occurs in the blood as a consequence of peripheral nutrition, but that it is formed during those processes which are dependent on the respiratory and circulatory functions, in which we must seek for the greater part of the carbonic acid which is exhaled, and for the principal source of animal heat. I refer to the active metamorphosis of the blood, or to the mutual action excited by the blood corpuscles, the plasma, and the oxygen held in solution in the blood, on each other."

Dr. Percy has made experiments corroborative of the views of Simon. He did not, however, observe any augmentation of the soluble salts, viz. phosphates, sulphates, and chlorides.

In relation to this subject, Simon alludes to the opinion expressed by Berzelius, that at least a portion of the sulphates and phosphates occurring in the urine, are derived from the oxidation of phosphorus and sulphur which previously existed as components of protein compounds, which become changed during the metamorphosis of the blood. This view I hold to be especially true as respects the phosphates, and would here refer the reader to a paper of mine printed in the Philosophical Magazine *, in which I showed that the amount of alkaline phosphate contained in the *serum* of arterial blood is much greater than in that of venous, and that the amount of such salt in venous serum can be at once increased by exposing the blood corpuscles to air, and consequently to the action of oxygen during the coagulation of the fluid.

I feel satisfied, indeed, from my results, that one great and essential difference between arterial and venous blood consists in the great excess of alkaline phosphate contained in the *serum* of the blood of the arteries as compared with that of the veins.

With respect to the quantity of chloride of sodium excreted by the urine, it is subject to great variation. Simon remarks, that the urine in disease is sometimes deficient in salts, and that this deficiency takes place at the expense of the chloride of sodium. He found but a trace of chloride of sodium in the urine of a patient suffering from typhus.

Dr. Bence Jones has made experiments on

* On a Function of the Red Corpuscles of the Blood, by G. Owen Rees.

the variation of the sulphates in urine, and has arrived at the following conclusions:—

1. The sulphates are increased by food, both animal and vegetable.
2. Exercise does not produce so marked an increase in the sulphates.
3. Sulphuric acid in *large* doses increases the proportion of sulphates; in small doses it produces little or no effect.
4. Sulphur, when taken, increases the sulphates in the urine, and sulphate of soda or magnesia produces the greatest effect on the quantity of sulphates in the urine.

With respect to the phosphates contained in the urine, Dr. Jones has arrived at the conclusion, that the quantity of *earthy* phosphates depends on the quantity contained in the ingesta, and that this is also the case with the *alkaline* phosphates. These latter, however, are to a certain extent increased by exercise.

URINE OF ANIMALS.

The urine of animals varies much in character, according to the kind of food taken. Thus, there are striking differences between the urine of the carnivora and the herbivora. The urine of carnivorous animals is generally acid when discharged, but becomes alkaline and ammoniacal very rapidly. The urine of herbivorous animals, on the contrary, is alkaline when passed, and contains a large proportion of alkaline and earthy carbonates. Simon, however, states the urine of horses immediately after it is passed, to be occasionally acid. The urine of the carnivora, according to the observations of Vanquelin and Hünefeld, contains neither the uric nor hippuric acids. Hieronymi, however, who examined the urine of the lion, the tiger, and the leopard, detected uric acid in small proportions. The urine of the herbivora contains hippuric acid in large quantities, in the form of hippurate of soda. No uric acid is present according to the analyses of most chemists, but traces of it have occasionally been found in the urine of the graminivora.

Hieronymi obtained the following result by the analysis of the mixed urines of the *lion, tiger, and leopard.* This may, therefore, be regarded as the type of the urine of the carnivora:—

Water - - - - - -	846·00
Urea, alcoholic extractive and free lactic acid - - - -	132·20
Uric acid - - - - -	0·22
Vesical mucus - - - - -	5·10
Sulphate of potassa - - -	1·22
Chloride of ammonium, and traces of chloride of sodium - -	1·16
Earthy phosphates - - - -	1·76
Phosphates of soda and potassa	8·02
Phosphate of ammonia - -	1·02
Lactate of potassa - - - -	3·30

The specific gravity of the urine of these large carnivorous animals varies, according to Hieronymi, from 1059 to 1076. It is clear when passed, and of a bright yellow colour.

The urine of the herbivora is turbid when passed, and generally possesses a lower specific gravity than that of carnivorous animals. Thus, the urine of horses, according to Simon, is about 1045. That of oxen, according to Von Bibra, varies from 1040 to 1032.

The following are two analyses of the urine of *horses* by Von Bibra:—

Water - - -	885·09	912·84
Urea - - - -	12·44	8·36
Hippuric acid - -	12·60	1·23
Watery extractive -	21·32	19·25
Alcoholic extractive -	25·50	18·26
Mucus - - -	0·05	0·06
Salts soluble in water -	23·40	40·00
Salts insoluble in water	18·80	

With respect to the hippuric acid present, Von Bibra found that it varied extremely in proportion in different specimens of urine. He never found that it became replaced by the benzoic acid when horses were exposed to excessive labour, an opinion which has been very generally received by chemists. He never, indeed, could detect benzoic acid under any circumstances, except in such small quantities as to require the assistance of the microscope to show its presence.

The deposit which causes the turbidity observed in the urine of the horse, is composed as follows, according to Von Bibra:—

Carbonate of lime - - -	80·9
Carbonate of magnesia - -	12·1
Organic matter - - - - -	7·0

The horses that supplied the above described specimens of urine, were fed on hay and oats, and used in agriculture.

Boussingault examined the urine of a horse fed on trefoil and vetches, and states its composition as follows:—

Water - - - - - -	910·76
Urea - - - - - -	31·00
Hippurate of potassa - -	4·74
Lactate of potassa - - -	11·28
Lactate of soda - - -	8·81
Bicarbonate of potassa - -	15·50
Carbonate of lime - - -	10·82
Carbonate of magnesia - -	4·16
Sulphate of potassa - - -	1·18
Chloride of sodium - - -	0·74
Silica - - - - - -	1·01
Phosphates,—none present.	

Chemists have described a red oil as existing in the urine of herbivorous animals, and have attributed the peculiar odour of the secretion to the presence of that substance.

Boussingault carefully examined the urine of horses with a view to obtain this oil for examination, but failed to extract it, though he operated on twenty-six gallons. He distilled the whole quantity, but no trace of oil came over into the receiver. All that he obtained was a colourless fluid, strongly impregnated with the odour of horse's urine.

He considers this odour dependent upon the presence of a volatile acid, and believes that the volatile red oil obtained by chemists results from the decomposition of the alkaline hippurates, and that it is not produced until the urine is evaporated to dryness.

The following are two analyses, by Von Bibra, of the urine of *oxen* obtained at different times. The animals had been fed on clover and hay :—

Water - - - -	912·01	923·11
Urea - - - -	19·76	10·21
Hippuric acid - -	5·55	12·00
Mucus - - -	0·07	0·06
Alcoholic extract -	14·21	10·20
Watery extract - -	22·48	16·43
Soluble salts - -	24·42	25·77
Insoluble salts - -	1·50	2·22

It will be perceived that the insoluble salts or *earthy* carbonates are in small proportion in the urine of oxen, while in the urine of horses they are present in about equal proportion to the *alkaline* carbonates. The urine of a cow, which was submitted to analysis by Boussingault, gave a result varying considerably from that obtained by Von Bibra from the urine of oxen, as above quoted. It yielded in 1000 parts: —

Water - - - - - -	921·32
Urea - - - - - -	18·48
Hippurate of potassa - -	16·51
Lactate of potassa - - -	17·16
Bicarbonate of potassa - -	16·12
Carbonate of magnesia - -	4·74
Carbonate of lime - - -	0·55
Sulphate of potassa - -	3 60
Chloride of sodium - -	1·52
Silica, a trace.	
Phosphoric acid, none.	

The great excess of the earthy salts observed in the urine of horses, as compared with that of oxen, is a remarkable circumstance, and would appear to be in some way connected with the difference in conformation of the two animals rather than on differences in diet. Thus the conditions alluded to pertained whether the horses were fed on hay and oats, or on trefoil and vetches. The oxen too, the urine of which was examined by Von Bibra, were fed on hay and clover, a diet closely resembling that of the horses ; but the earthy salts were, notwithstanding, found in the urine in very small proportion.

Vogel has examined the urine of the elephant and the rhinoceros. That of the *elephant* possessed the following characters :

1. It was turbid, owing to carbonates of lime and magnesia.
2. It contained more urea than the urine of the rhinoceros.
3. No hippuric acid was present.*

The urine of the *rhinoceros* is described as follows :—

1. It was turbid, owing to the presence of carbonate of lime, earthy phosphates, silica and peroxide of iron.
2. It gave out the odour of formic acid.
3. It yielded hippuric acid in considerable quantity.

* Brandes believed he detected the hippuric acid in this urine in combination with urea and an alkali.

Chevreul examined the urine of the *camel*.

1. It contained no uric acid.
2. Urea was present in abundance.
3. No phosphates could be detected.
4. The chief constituents, in addition to urea, were chloride of sodium, hippurate of soda, carbonate of soda, sulphate of potassa, carbonate of ammonia, and traces of sulphate of soda and oxide of iron.

Chevreul considers this urine to contain a volatile oil to which it owes its colour, and to which he ascribes the property it possesses of becoming red on the addition of the mineral acids.

The urine of *pigs* has been examined by Lassaigne, Van Setten, and Boussingault. Its specific gravity appears to vary between 1003 and 1013.

Van Setten's analysis is as follows :—

Water - - - - - -	990·028
Urea - - - - - -	0·750
Uric acid - - - - -	0·195
Watery extractive - -	1·708
Alcoholic extractive - -	1·105
Resinous matter - - -	0·425
Albumen and mucus - -	0·721
Lactic acid - - - - -	0·490
Stearin - - - - -	0·092
Sugar - - - - -	0·375
Phosphate of soda - -	1·376
Sulphate of potassa, chlorides of potassium and sodium -	2·075
Sulphates of lime and magnesia	0·425
Sulphate of ammonia - -	0·196
Chloride of ammonium - -	0·010

Von Bibra describes the urine of the pig as clear, odourless, and of alkaline re-action. He could not detect uric, hippuric, or benzoic acid in it when operating on three ounces of the fluid; but he subsequently obtained microscopic crystals of hippuric acid. No trace of uric acid could be discovered.

Boussingault could not detect hippuric acid in the urine of a pig fed on potatoes and salt. He varied the diet by the addition of green trefoil, but still he could not discover the acid.

Von Bibra analysed the urine of the *goat*. He found it alkaline and of pungent odour, of specific gravity 1008 or 1009. The animals had been kept in a stable and fed on bad hay. From two analyses made on 1000 parts, the following results were obtained :—

Water - - - -	980·07	983·99
Urea - - - -	3·78	0·76
Hippuric acid - -	1·25	0·88
Alcoholic extractive -	4·54	4·66
Watery extractive -	1·00	0·56
Mucus - - -	0·06	0·05
Soluble salts - -	8·50	8·70
Insoluble salts - -	0·80	0·40

In this urine, as in that of oxen, the alkaline carbonates greatly predominate over the earthy salts.

According to Vanquelin, the urine of the *beaver* contains the colouring matter of the bark of the willow, which is the food of the animal. He detected it by using alum as a mordant for pieces of cloth soaked in the urine. He detected the presence of bicarbonates of lime and magnesia, and hippurate of soda. He could not find any phosphates, nor uric acid.

The urine of *rabbits* and *guinea-pigs* has an alkaline reaction, and contains alkaline and earthy carbonates. It presents no peculiar qualities.

Von Bibra analysed the urine of the *hare*, both in summer and in winter. In December he found the urine turbid and alkaline, depositing phosphate of magnesia. In June it was only faintly alkaline. The proportion of earthy phosphates present was more than twice as great in summer as in winter, which Simon remarks upon as probably caused by the great difference in the food of the hare during the two seasons. With respect to his examination of the urines of herbivora, Von Bibra states he obtained in most of them indications of the presence of humic acid, or a substance closely allied to it.

As regards these analyses, which are quoted from Simon's work on animal chemistry, it would appear a matter of regret that experiments have not been made on an extended scale on the same animal, under different conditions; more especially under variations in food, temperature, and moisture. Such form of inquiry could not fail to be of eminent service to physiology, and much light might thus be thrown on the question of diet, in respect to constitution and predisposition to disease, a subject greatly needing elucidation, notwithstanding the labour and ingenious activity which has been devoted to it during the last few years.

Urine of Birds, &c. — The urine of birds is excreted from the cloaca in the form of a thin paste, which hardens by exposure. Urate of ammonia is the principal constituent. The urine of carnivorous birds, however, contains urea in considerable quantity, which distinguishes it from that of birds feeding on vegetable substances. Chemists have also described a green colouring matter, as peculiar to the urine of carnivorous birds.

The constituents of the urine of the ostrich, according to Vanquelin and Fourcroy, are —

Uric acid.
Sulphate of potassa.
Sulphate of lime.
Chloride of ammonia.
Oily matter.
A peculiar animal matter.
Acetic acid (?)

The urine of *serpents* is excreted in the form of a white, earthy mass. It is made up of uric acid, combined with potassa, soda, and ammonia. Phosphate of lime is also present.

Cass and Henry state that they obtained urea from the urine of serpents. That principle was sought for in vain, however, by Vanquelin and Fourcroy.

Simon gives the following as the result of an analysis of the urine of a *rattle-snake*. He operated on 100 parts, weighed, when quite dry.

Free uric acid, some fat, and extractive matters	56·4
Urate of ammonia	31·1
Urate of soda, with some chloride of sodium	9·8
Urate of lime	1·4
Phosphate of lime	1·3

Dr. J. Davey examined the urine of the *bull-frog* (*rana taurina*). He found it of specific gravity 1003. Urea, chloride of sodium, and a little phosphate of lime were also present.

Marchand's analysis of the urine of the *land-tortoise* (*testudo tubulata*) yielded the following result, —

Water	950·64
Urea	6·40
Uric acid	17·25
Salts and indeterminate organic matter	25·70

There was no hippuric acid in this urine. It possessed a faintly acid reaction, and is stated to have presented the appearance of pus. Ether extracted a brownish-coloured fat, having an urinous odour.*

URINE IN DISEASE.

With respect to the urine of the human subject, it has been shown that considerable variation occurs *in health* according to the modifications which may have been made in diet. The urine of the lower animals is doubtless, to a certain extent, amenable to the same rule. We observe also striking differences in the urine of herbivora fed on similar diets, as has been noticed above in the case of the horse and the ox, both graminivorous animals and fed nearly alike for experiment, but whose urine showed, on analysis, very marked and important differences. This variation in the result of the digestive process would appear, in such case, to depend upon the internal arrangement of the chylopoietic organs, and should perhaps more especially be attributed to differences in the minute anatomy of the mucous secreting surfaces. Certain fixed variations, then, are to be observed in the constitution of the urine as results of difference in healthy anatomy; and so in the same way, when certain organs are affected by disease, we find a set of changes occurring in the urine quite as marked in character; and it is of especial moment to the physician that he should be able easily and accurately to appreciate them. While studying those conditions, it is however of the highest importance that the changes which diet, the temperature to which the body may have been exposed, the amount of moisture in the air, &c., should be considered, and that the physician should be able to separate in his mind those phenomena which are indicative

* Quoted by Simon from Erdmann and Marchand's Journal, 1845. iv. 4.

of morbid change in important organs, from such as may merely be the results of actions occurring in perfect health, and consistent with its preservation.

Many pathological conditions of the urine are indeed closely simulated by the unimportant changes to which I have alluded. Thus the urine of diabetes insipidus, often a most severe and unmanageable disease, can scarcely be distinguished from that *occasionally* secreted by healthy persons exposed to cold or moisture, or both, without sufficient exercise to maintain the full amount of cutaneous exhalation. Such a specimen, were it examined carelessly, or allowed to guide the judgment without due attention to concomitant circumstances and previous history, might lead (and I may say has led) to mistakes both injurious to the patient and vexatious to the practitioner.

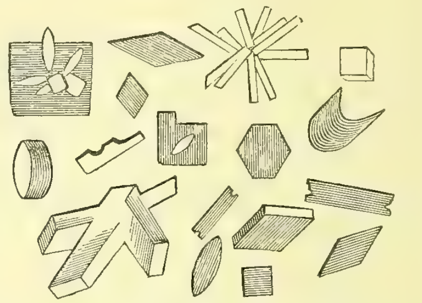
In studying the pathology of the urine, it is also especially important that we should not give undue regard to chemistry, nor be led astray by theories and generalisations such as that fascinating science so constantly would tempt us to enter upon. It must be remembered that in most cases chemistry as yet only assists us in the detection of symptoms, and in the present state of our knowledge can only thus far serve us, but must fail as a guide to a true knowledge of diseased action or appropriate methods of treatment. This consideration, however, is far from depressing to those who regard the subject in a truly philosophical spirit; for be it remembered that when we have detected sugar or albumen in the urine, and when the modes of examination are rendered both easy and exact by chemical labour, we have reaped a most valuable advantage by becoming acquainted with a symptom, without which, we should have been left in such a position that we might have despaired of ever obtaining an insight into the pathology of two most important diseases. A knowledge of symptoms thus acquired by chemistry at once enables us to make use of a large amount of valuable information derived from experience, and to bring to our assistance remedies which would not otherwise have suggested themselves, or perhaps have been considered inapplicable. It has unfortunately too often been attempted to push chemical reasoning to the uttermost in considering urinary diseases; and there is a class of persons, greatly increasing in the present day, who have thus inflicted much mischief on a science which requires great labour in its prosecution, and consequently is the more eagerly condemned as useless by the idle or ungifted practitioner. If we confine the application of chemistry, in urinary disease, merely to symptomatology, it is easy to show that we are deeply indebted to the science, and it is the especial duty of those who are most conversant with it to regard its further application with great jealousy.

I shall now proceed to describe the urine as it appears in various diseased conditions of the body, beginning with those variations from healthy constitution characterised by the existence of deposits of various kinds known as urinary deposits. It is not, however, within the province of this article to enter upon any pathological considerations relating to these abnormal conditions.

Lithic acid Deposit.

This deposit (commonly known as "red sand" or gravel) occurs in urine in many forms, the crystals as seen under the microscope presenting the appearances figured below (*fig.* 791).

Fig. 791.

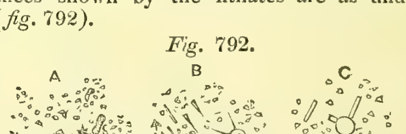


Urine depositing lithic acid is generally of a deep yellow colour, and acid beyond the normal degree. Its specific gravity is mostly somewhat above that of health. Lithic acid occasionally deposits from urine in an amorphous concrete form, and is seen in rounded or flattened masses adhering to the bottom of the chamber vessel. This latter kind of deposit is the most dangerous as respects the formation of calculi.

Deposit of Lithates.

This form of deposit, known as the lateritious deposit, from ts resemblance to brick dust, consists of lithic acid combined with ammonia, and in some few cases with lime, magnesia, or soda. The microscopic appearances shown by the lithates are as under (*fig.* 792).

Fig. 792.

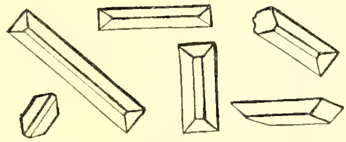


The spheroidal masses with projecting needle points (B), I believe to indicate lithate of lime, while the masses having projecting crystals with truncated ends (C), I believe consist chiefly of lithate of magnesia. The lithate of ammonia is amorphous, sometimes spheroidal with adhering spicula, or is seen making up a dotted background (A). Urine depositing the lithates is generally of a higher specific gravity than natural, and is passed clear. After the deposit has occurred, the application of a gentle heat is always sufficient to re-dissolve it.

Deposit of Earthy Phosphates.

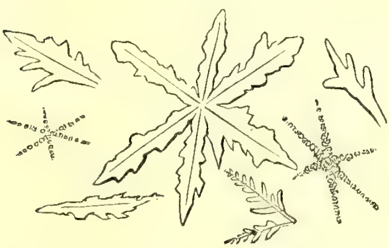
The earthy phosphates, consisting of magnesia in combination with ammonia and phosphoric acid, are seen as deposits in the urine in two forms, viz. as a monobasic and a bibasic salt. The monobasic phosphate, which is seen in neutral or only slightly alkaline urine, presents the microscopic appearances as under (*fig.* 793).

Fig. 793.



The bibasic salt, which is observed in highly ammoniacal urine, gives the following figures (*fig.* 794).

Fig. 794.



Urine depositing the first of these two varieties of sediment is generally of lighter colour than natural, and of moderately high specific gravity.

The second variety, if not occasioned by the use of alkaline remedies, generally indicates important mischief in some part of the urinary apparatus, and is often combined with large quantities of epithelium, mucus, pus, and blood corpuscles.

Deposit of Oxalate of Lime.

This deposit, which is composed of lime in combination with an acid foreign to the constitution of healthy urine, presents itself under the microscope in the following forms, first described by Dr. Golding Bird (*fig.* 795).

Fig. 795.

The appearance of dark crystals, looking like cubes, is observed when this deposit is allowed to dry. The transparent spot in the centre is caused by reflection from the sides of the octohedron.

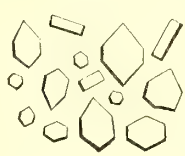
Urine depositing oxalate of lime is generally of about the normal specific gravity. It occasionally has a light greenish hue. The deposit when allowed to collect in a glass vessel is rarely seen otherwise than as a floating cloud collecting at bottom, and closely resembling the appearance which would be put on by the presence of an excess of the mucus of the bladder natural to the urine.

It has recently been stated, by Dr. Frick, of Baltimore, that the crystalline masses, in the form of dumb-bells, described by Dr. Bird as consisting of oxalate of lime, are really composed of lithic acid. It is true that lithic acid occasionally assumes a form more or less resembling the dumb-bells figured by Dr. Bird, but scarcely so nearly as to be easily mistaken for them. Dr. Marris Wilson has also recently shown that lithic acid may be made to assume a form nearly approaching in character to the dumb-bells. I have examined, with Dr. Bird, some specimens of the dumb-bells, and am satisfied that those we operated upon were composed of lime in combination with an organic acid. In a paper recently published by Dr. Bird in the Medical Gazette, some reasons are given by him for believing that acid to be the oxaluric, and not the oxalic, and there would appear good grounds for the adoption of that opinion.

Deposit of Cystine.

This substance, which is not one of the ingredients of normal urine, is an organic body, occasionally existing as a deposit in the form of flattened hexagonal plates. Under the microscope it presents the following appearances (*fig.* 796).

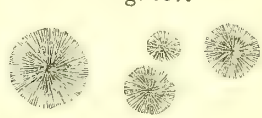
Fig. 796.



Carbonate of Lime Deposit.

This rare deposit exists in the form of spherical masses, more or less crystalline, and apparently made up of slender rhomboidal prisms, diverging from a centre. It presents the following appearance under the microscope (*fig.* 797).

Fig. 797.



Hippuric Acid.

This exists occasionally in excessive quantity in human urine in disease. Under the microscope it shows the following appearance (*fig.* 798).

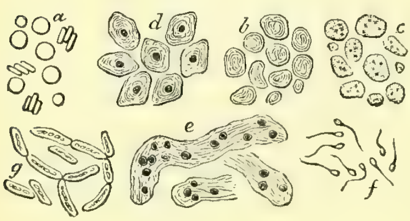
Fig. 798.

Besides these more or less crystalline deposits, the urine in disease frequently contains blood, mucus and pus corpuscles, and also epithelial scales, and other bodies of various kinds; with all of which it is necessary the physician should be familiar, as symptomatic of different diseases.

In order satisfactorily to detect these, the microscope is of course indispensable.

The following are the appearances shown by these more or less organised bodies, when existing in the urineg (*fig.* 799).

Fig. 799.



a, Blood corpuscles endosmosed or distended, owing to the entrance of the urine through their membrane. This effect is the consequence of the contained fluid of the corpuscles having been heavier than the urine in which they float, in virtue of which condition more fluid passed into the corpuscle than could escape out. *b*, Mucous corpuscles. *c*, Pus corpuscles. *d*, Scales of epithelium. *e*, Fibrinous casts of the urinary tubules of the kidney, seen in the morbus Brightii, deposited from albuminous urine — spheroidal epithelium from the tubules is seen embedded in these fibrinous casts. *f*, Spermatozoa. *g*, Torula diabetica, seen in diabetic urine during its fermentation.

A tendency to the secretion in excessive quantity of the unorganised deposits, such as lithic acid and the lithates, oxalate of lime, &c., leads not unfrequently to the formation of urinary calculi. These are either made up, as is most frequently the case, of several of the constituents of the urine, or may be entirely constituted of one of them.

The following table, constructed by the late Dr. Prout, exhibits a general view of the relative frequency of the different kinds of urinary calculi in England, Swabia, Germany, and Denmark. The hospitals of St. Bartholomew and of Guy in London, and those of Norwich, Manchester, and Bristol, principally supplied the specimens quoted in this table.

The ingredients of particular species of calculi included between parentheses, are to be considered as existing in a mixed state.

* For further information respecting urinary deposits, I must refer to Dr. Golding Bird's work on the subject, and my Treatise " on Analysis, and the Treatment of Urinary Diseases."

General Character of Calculi.	Particular Species of Calculi.	England.					Continent.		Particular Totals.	General Totals.
		Bartholomew's Hospital, London.	Guy's Hospital, London.	Norwich Hospital.	Manchester Hospital.	Bristol Hospital.	Swabia, Germany.	Copenhagen, Denmark.		
1. *Lithic acid.*	Lithic acid, nearly pure - -	11	16	164	...	...	7	32	230	448
Lithate of ammonia.	Lithate of ammonia, nearly pure -	...	...	55	...	...	1	3	59	
	Lithate of ammonia, mixed with variable proportions of the lithate and				71	74	...	...	145	
	oxalates of lime and phosphates -	8	6	...	...	...	...	...	14	
2. *Oxalate of lime.*	Oxalate of lime, nearly pure - -	8	22	21	11	33	3	...	98	98
3. *Cystic oxide.*	Cystic oxide, nearly pure - -	2	1	...	2	...	...	...	5	5
4. *Phosphates.*	Phosphate of lime, nearly pure -	4	3	5	...	1	...	...	13	13
	Triple phosphate, nearly pure -	1	2	...	...	1	...	8	12	12
	Mixed phosphates - - -	10	24	35	4	18	7	8	106	106
	(Phosphate of lime, with carbonate of lime) - - - - -	...	...	...	...	...	1	1	2	2
	——— mixed with a little lithic acid	...	...	...	18	...	...	...	18	18
	——— deposited on foreign bodies -	3	...	...	...	...	...	2	5	5
Carbonate of lime.	(Carbonate of lime and silex) -	...	...	...	...	...	...	1	1	1
Silex.	Siliceous - - - -	...	...	...	...	...	...	1	1	1
5. *a. Alternating calculi* composed of *two* layers.	Lithic acid, and lithate of ammonia -	4	...	49	...	...	...	1	54	
	——— and oxalate of lime -	3	...	10	...	...	53	...	66	
	——— and phosphate of lime -	...	...	8	...	...	...	...	8	
	——— and mixed phosphates -	6	...	15	39	12	9	13	94	

General Character of Calculi.	Particular Species of Calculi.	England. Bartholomew's Hospital, London.	England. Guy's Hospital, London.	England. Norwich Hospital.	England. Manchester Hospital.	England. Bristol Hospital.	Continent. Swabia, Germany.	Continent. Copenhagen, Denmark.	Particular Totals.	General Totals.
5. *a. Alternating calculi* composed of *two* layers.	(Lithic acid, lithate of ammonia,) and (lithate of magnesia and mixed phosphates) - - - - -	...	...	...	...	...	...	2	2	
	(Lithic acid and lithate of lime) and mixed phosphates) - - -	...	...	...	...	...	...	2	2	
	(Lithic acid, lithate and oxalate of lime,) and lithic acid - -	...	...	...	...	...	...	27	27	
	(Lithic acid, lithate of ammonia and oxalate of lime,) and mixed phosphates	...	...	...	...	...	...	2	2	
	Lithate of ammonia and lithic acid -	2	...	21	...	...	...	...	23	
	———— and oxalate of lime -	7	...	63	...	...	...	...	70	
	———— and phosphate of lime -	...	...	9	...	...	...	...	9	
	———— and mixed phosphates -	13	...	22	...	...	...	...	35	
	Lithate of soda and lithic acid -	...	...	...	...	...	...	1	1	566
	Lithate of lime, and (lithate and oxalate of lime and lithate of ammonia)	...	...	...	...	...	...	1	1	
	(Lithate and oxalate of lime,) and oxalate of lime - - -	...	...	...	...	...	...	8	8	
	(Lithate of ammonia and of lime,) and lithate of ammonia and lime, alternately - - - -	...	...	...	...	...	...	2	2	
	Oxalate of lime and lithic acid -	3	...	15	11	29	...	3	61	
	——— and lithate of ammonia -	1	...	3	...	...	...	...	4	
	——— and phosphate of lime -	...	...	7	...	...	...	...	7	
	——— and mixed phosphates -	13	...	20	16	32	...	...	81	
	——— and (lithic acid and mixed phosphates) - -	...	...	...	...	...	...	1	1	
	——— and silex - - -	...	...	1	...	...	...	...	1	
	Mixed phosphates and oxalate of lime	...	...	1	...	...	...	...	1	
	——— and phosphate of lime -	...	...	2	...	...	...	...	2	
	Phosphate of lime and mixed phosphates - - - -	...	...	3	...	...	...	...	3	
	——— and oxalate of lime -	...	...	1	...	...	...	...	1	
b. Alternating calculi composed of *three* layers.	Lithic acid, oxalate of lime, and phosphate of lime - - - -	...	...	2	...	...	...	...	2	
	———, oxalate of lime, and lithate of ammonia - - - - -	...	...	4	...	...	...	...	4	
	———, oxalate of lime, and lithic acid	...	...	5	...	...	...	...	5	
	———, lithate of ammonia, and oxalate of lime - - - - -	...	...	2	...	...	...	...	2	
	———, lithate of ammonia, and lithic acid - - - - -	...	...	2	...	...	...	...	2	
	———, lithate of ammonia and phosphates - - - - -	3	...	2	...	...	...	...	5	
	——— oxalate of lime and phosphates - - - - -	1	...	3	...	...	...	...	4	
	(Lithic acid and lithate of lime,) oxalate of lime and mixed phosphates -	...	...	...	...	...	...	2	2	
	(Lithic acid, lithate and oxalate of lime) lithic acid and mixed phosphates -	...	...	...	...	...	...	17	17	
	Lithate of ammonia, oxalate of lime, and mixed phosphates - -	13	...	13	...	...	...	...	26	
	———, oxalate of lime, and phosphate of lime - - - -	...	...	13	...	...	...	...	13	
	———, oxalate of lime and lithic acid	1	...	16	...	...	...	...	17	
	———, oxalate of lime, and lithate of ammonia - - - - -	1	...	7	...	...	...	...	8	
	———, phosphate of lime, and lithate of ammonia - - -	...	...	1	...	...	...	...	1	
	———, phosphate of lime and lithic acid - - - - -	...	...	1	...	...	...	...	1	172
	———, phosphate of lime and oxalate of lime - - - - -	...	...	1	...	...	...	...	1	
	———, phosphate of lime, and mixed phosphates - - - - -	...	...	4	...	...	...	...	4	

General Character of Calculi.	Particular Species of Calculi.	England. Bartholomew's Hospital, London.	England. Guy's Hospital, London.	England. Norwich Hospital.	England. Manchester Hospital.	England. Bristol Hospital.	Continent. Swabia, Germany.	Continent. Copenhagen, Denmark.	Particular Totals.	General Totals.
b. *Alternating calculi* composed of *three* layers.	Lithate of ammonia, lithic acid, and phosphates - - - -	1	...	6	...	...	...	...	7	
	———, lithic acid, and lithate of ammonia - - - - -	...	...	1	...	...	...	...	1	
	———, lithic acid, and phosphate of lime	...	...	4	...	...	...	...	4	
	———, lithic acid, and oxalate of lime	...	...	3	...	...	...	...	3	
	(Lithate and oxalate of lime,) oxalate of lime, and mixed phosphates -	...	...	...	...	...	...	13	13	
	(Lithate and oxalate of lime,) (ditto alternately,) and phosphates -	...	...	...	...	...	...	3	3	
	Oxalate of lime, lithic acid and lithate of ammonia - - -	1	...	3	...	...	...	...	4	
	———, lithic acid and oxalate of lime	1	...	3	...	...	...	...	4	
	———, lithic acid, and phosphate of lime - - - -	...	...	1	...	...	...	...	1	
	———, lithic acid, and mixed phosphates - - - -	...	...	5	7	...	...	...	12	
	———, lithate of ammonia, and phosphate of lime - - -	...	...	3	...	...	...	...	3	
	———, lithate of ammonia, and oxalate of lime - - - -	...	...	2	...	...	...	...	2	
	Mixed phosphates, phosphate of lime, and mixed phosphates - -	...	...	1	...	...	...	...	1	
c. *Alternating calculi* composed of *four* layers.	Lithic acid, lithate of ammonia, lithic acid, and lithate of ammonia -	...	...	1	...	...	...	...	1	
	———, oxalate of lime, lithate of ammonia, and phosphate of lime -	...	...	1	...	...	...	...	1	
	———, oxalate of lime, lithic acid and oxalate of lime - - -	...	...	1	...	...	...	...	1	
	———, oxalate of lime, lithic acid, and lithate of ammonia - - -	...	...	2	...	...	...	...	2	
	Lithate of ammonia, oxalate of lime, lithate of ammonia, and phosphates	...	...	5	...	...	...	...	5	
	———, oxalate of lime, lithate of ammonia, and oxalate of lime - -	...	...	3	...	...	...	...	3	
	———, oxalate of lime, phosphates and oxalate of lime - - -	...	...	2	...	...	...	...	2	
	———, oxalate of lime, lithic acid, and lithate of ammonia - -	...	...	1	...	...	...	...	1	
	———, oxalate of lime, phosphate of lime, and phosphates - -	...	...	1	...	...	...	...	1	25
	———, oxalate of lime, lithic acid, and phosphates - - -	...	...	1	...	...	...	...	1	
	———, oxalate of lime, lithic acid, and oxalate of lime - -	...	...	1	...	...	...	...	1	
	———, oxalate of lime, lithate of ammonia, and lithic acid - -	...	...	1	...	...	...	...	1	
	———, phosphate of lime oxalate of lime, and lithate of ammonia -	...	...	1	...	...	...	...	1	
	Oxalate of lime, lithic acid, lithate of ammonia, and lithic acid - -	...	...	1	...	...	...	...	1	
	———, lithic acid, oxalate of lime, and phosphate of lime - - -	...	...	1	...	...	...	...	1	
	———, lithic acid, oxalate of lime, and phosphates - - - -	...	...	1	...	...	...	...	1	
	———, lithic acid, lithate of ammonia, and phosphates - - -	...	...	1	...	...	...	...	1	
d. *Alternating calculi* composed of *several* layers.	Composition not mentioned - -	8	6	...	...	10	...	...	24	24
6. *Mixed* or *compound* calculi.	Mixture not mentioned - -	...	7	...	8	8	...	...	23	23
	Fibrous matter and phosphates -	...	...	...	...	...	...	1	1	1
		129	87	663	187	218	81	155	...	1520

To this table Dr. Prout appends the following valuable remarks in his work "On Stomach and Urinary Diseases": —

"In this table the urinary calculi contained in the museums of Bartholomew's and Guy's Hospitals in London, and of the provincial hospitals of Norwich, Manchester, and Bristol, are contrasted with the calculi existing in Swabia in Germany, and in Copenhagen in Denmark. The data here collected are too limited to throw much light on the relative prevalence of calculous affections in different parts of England, much less in England as compared with the different countries of Europe; yet in other points of view, and particularly in demonstrating the relative prevalence of the different species of calculi, and the order of the succession of the different layers of which calculi are composed, &c., they are highly interesting and important.

"In this table, the whole of the data comprising the analysis of 1520 calculi, are collected into one point of view, under the general heads of 1. *Lithic acid*, 2. *Mulberry*, 2. *Cystic oxide*, 4. *Phosphatic*, 5. *Alternating*, and 6. *Compound Calculi.*

"On each of these heads we shall make a few remarks.

"1. *Of lithic acid calculi.*—The proportions of *pure lithic acid* calculi to the whole numbers contained in the different museums, are as follow: — In Bartholomew's Hospital, as 1 : $11\frac{6}{11}$; in Guy's Hospital, as 1 : 5+; in the Norwich Hospital, as 1 : 4+; in Swabia, as 1 : $11\frac{4}{7}$; in Copenhagen, as 1 : 5—. The relative proportions of pure lithic acid calculi in the Manchester and Bristol Museums are not mentioned; hence, abstracting the Manchester and Bristol, the general proportion of pure lithic acid calculi is as 1 : $6\frac{1}{2}$, nearly.

"The relative proportions of calculi in the different museums, composed *essentially of lithic acid*, (*i. e.* consisting of pure lithic acid, lithate of ammonia, and the latter ingredient mixed with minute quantities of the lithate and oxalate of lime, and the phosphates,) are, in Bartholomew's Hospital, as 1 : 7—; in Guy's Hospital, as 1 : 4—; in the Norwich Hospital, as 1 : 3+; in the Manchester Hospital, as 1 : $2\frac{1}{2}$+; in the Bristol Hospital, as 1 : 3—; in Swabia, as 1 : 10+; and in Copenhagen, as 1 : $4\frac{1}{2}$—. The general proportion in all the collections is as 1 : $3\frac{1}{2}$—.

"If we take into account *all* the calculi of which the lithic acid or its compounds form the *nucleus*, the proportions of calculi originating with this principle (and which probably would otherwise have not been formed) is very much greater. Thus in Bartholomew's Hospital the proportion of calculi containing the lithic acid or some of its compounds as a nucleus, is to the whole number of calculi as 1 : $1\frac{3}{4}$—; in Guy's Hospital, as 1 : 4—, (not fairly comparable, as the calculi do not appear to be divided;) in the Norwich Hospital, as 1 : $1\frac{1}{4}$+; in the Manchester Hospital, as 1 : $1\frac{3}{4}$—; in the Bristol, as 1 : $2\frac{1}{2}$+; in Swabia, 1 : $1\frac{1}{6}$+; and in Copenhagen, as 1 : $1\frac{1}{5}$. The relative proportions of all the calculi originating in some form or combination of lithic acid, in all the different collections, is nearly as 1 : $1\frac{1}{2}$, which is equal to saying, that if a lithic acid nucleus had not been formed and detained in the bladder, two persons at least out of three who suffer from calculus would have never been troubled with that affection.

"*Of mulberry or oxalate of lime calculi.*— The proportions of mulberry calculi in the different hospitals are nearly as follow: in Bartholomew's Hospital, as 1 : 16+; in Guy's Hospital, as 1 : 4—; in the Norwich Hospital, as 1 : $31\frac{1}{2}$—; in the Manchester Hospital, as 1 : 17; in the Bristol Hospital, as 1 : $6\frac{2}{3}$—; in Swabia, as 1 : 27; in Copenhagen there does not appear to be any calculus composed throughout of oxalate of lime; but if we take the nearest approach to such composition, in which calculi are composed principally of this salt with a mixed nucleus, likewise containing oxalate of lime, the proportions will be as 1 : $19\frac{1}{2}$—; the general proportions in all the museums are as 1 : $14\frac{1}{3}$.

"If we take into account *all* the calculi of which the oxalate of lime constitutes more or less of the nucleus, the proportions in the different museums will be, — in Bartholomew's, 1 : $4\frac{3}{4}$+; in Guy's, 1 : 4—; in Norwich, 1 : $7\frac{1}{4}$+; in Manchester, 1 : $4\frac{1}{6}$+; in Bristol, 1 : $3\frac{1}{3}$—; in Swabia, 1 : 27; and in Copenhagen, 1 : $2\frac{1}{10}$+. The general proportion of calculi, into the nucleus of which oxalate of lime largely enters, in all the museums, is as 1 : $4\frac{1}{3}$+; which is equivalent to saying, that if a mulberry stone had not been formed and detained in the bladder, two persons out of about nine who suffer from calculus would not have been troubled with that affection.

"3. *Of cystic oxide calculi.* — Of this rare form of urinary calculus, four out of the seven museums contain no specimen. Calculi of this substance exist in the museums of Bartholomew's, Guy's, and the Manchester Hospitals, amounting altogether to five only. Hence the general proportion to the whole number of cystic oxide calculi examined, is only as 1 : 304.

"4. *Of phosphatic calculi.* — Calculi composed throughout of the phosphates are comparatively of uncommon occurrence; while calculi consisting *externally* of the phosphates, as will be presently shown, are the most frequent of all others. At present we have to do with calculi composed essentially of the phosphates.

"The proportion of calculi composed of the phosphate of lime, in Bartholomew's Hospital, is as 1 : $32\frac{1}{4}$; in Guy's Hospital, as 1 : 29; in the Norwich Hospital, as 1 : $132\frac{2}{3}$; in the Bristol, as 1 : 155. The other museums contain no specimen. The general proportion of phosphate of lime calculi, to the whole number, is as 1 : 117—.

"The proportion of calculi composed of the pure triple phosphate is still less; thus in Bartholomew's Hospital the proportion is as 1 : 129 ; in Guy's, as 1 : 43½ ; in the Bristol, as 1 : 218 ; in Copenhagen, as 1 : 19½—. The other museums contain no specimen. The general relation of the triple phosphate in all the collections, is as 1 : 126⅗.

"On the other hand, the proportion of calculi composed of the mixed phosphates is very considerable ; thus, in Bartholomew's Hospital, the proportion is as 1 : $12\frac{9}{10}$; in Guy's, as 1 : 3½+ ; in the Norwich, as 1 : 19— ; in the Manchester, (including those containing a little lithic acid,) as 1 : 8½ ; in the Bristol, as 1 : 12 + ; in Swabia, as 1 : 11½+; in Copenhagen, as 1 : 19⅜. The relative proportion of the mixed phosphates in all the collections is as 1 : 12¼+.

"Under the head of the phosphates are included a few rare specimens of other calculi, *e. g.* carbonate of lime and siliceous calculi. Of these two varieties, there is only one of each reported to exist in the Copenhagen collection ; and one containing silex in the Norwich collection.

"The general proportion of all the calculi arranged under the heads of the phosphates, in the different museums, is as 1 : 10—.

"5. *Of alternating calculi.* — Calculi composed of different layers constitute by far the most frequent results of urinary diseases ; of the successive forms assumed by which, they may be said to constitute the index. We shall first consider the relative proportions of the calculi composed of two, three, and four deposits ; and afterwards of the whole conjointly.

"The proportion of alternating calculi composed of *two* deposits is, in Bartholomew's Hospital, as 1 : 2½— ; in Guy's, none are reported, probably on account of the calculi not having been divided ; in Norwich, the proportion of alternating calculi composed of two layers is stated to be as 1 : 2⅔— ; in Manchester, as 1 : 2⅚ ; in the Bristol, as 1 : 3— ; in Swabia, as 1 : 1⅓+ ; and in Copenhagen, as 1 : 2½—. The proportion of alternating calculi composed of two layers, in the conjoint collections, is as 1 : 2⅗+.

"The proportion of alternating calculi composed of *three* deposits, is, in Bartholomew's Hospital, as 1 : 6— ; in Guy's Hospital, none is reported ; in the Norwich Hospital, the proportion is as 1 : 6+ ; in the Manchester, as 1 : $26\frac{5}{7}$; in the Bristol and Swabia collections, none is reported ; in Copenhagen, the proportion is stated to be as 1 : 4½—. The proportion in all the collections, is as 1 : 8⅞—.

"Alternating calculi composed of *four* deposits are only reported to exist in the Norwich Hospital, and the proportion stated is as 1 : 26½+. In the different collections there are twenty-four alternating calculi, the composition of which is not stated. The proportion of all the varieties of alternating calculi in the different collections, is somewhat more than one-half; that is, as 1 : 2—.

"6. *Of mixed or compound calculi.* — In one sense of the term, all calculi may be said to be *mixed* or *compound*, as there are perhaps none absolutely pure, *i.e.*, formed of a single ingredient. But in the sense in which the term is here applied, namely, as expressive of calculi composed of different ingredients mixed together in large or nearly equal proportions, compound calculi may be said to be rare. The most usual mixtures consist of the lithate of ammonia and of lime; of the oxalate, carbonate, and phosphate of lime ; of the lithate of ammonia, and the mixed phosphates, &c. ; and such mixtures are usually confined to small calculi or calculous nuclei. Calculi composed of pure lithic acid, or of any other pure ingredient, with the phosphates or other compounds, do not appear to exist ; at least I have met with no such mixtures.

"Lastly, it remains to make a few remarks on the *order* of calculous deposits ; an inquiry that throws considerable light on the laws of their formation and general pathology.

"On reference to the table it will be found, that in the different alternating calculi, the ratio in which the oxalate of lime succeeds to lithic acid, is as 1 : 15⅗+ ; on the contrary, that the ratio in which lithic acid succeeds to oxalic acid, is as 1 : $13\frac{5}{23}$. Hence the alternation of the two ingredients may be considered as nearly equal. It will be found, however, that the oxalate of lime succeeds to the lithate of ammonia, &c., more frequently than to lithic acid; thus the ratio in which the oxalate of lime succeeds to the lithate of ammonia was 1 : 9⅝—. On the contrary, the ratio in which the lithate of ammonia succeeds to the oxalate of lime, is only as 1 : 38 ; a very striking distinction. The ratio in which the phosphates succeed to lithic acid, is as 1 : 9⅙— ; in which the phosphates succeed to the lithate of ammonia, is as 1 : 12½— ; and in which the phosphates succeed to the oxalate of lime, is as 1 : 7½+. On the contrary, three instances only occur in which the lithic acid or lithate of ammonia succeeds to a phosphate ; and the proportion in which the oxalate of lime succeeds to the phosphates is as 1 : 253⅓ only. The general proportion in which the phosphates succeed to the other ingredients in all the collections, is as 1 : $4\frac{1}{15}$+. Hence the generality of the important law alluded to in various parts of this volume, *that in urinary calculi a decided deposition of the mixed phosphates is not followed by other depositions.*"

The following table, constructed by Dr. Prout, illustrating the frequency of calculous affections at different ages, and in the different sexes, is from a paper published by Mr. Smith in the eleventh volume of the Med. Chirurg. Transactions, and from "A Treatise on the Formation, Constituents, and Extraction of Urinary Calculi. By John Green Crosse, Esq., Surgeon to the Norfolk and Norwich Hospital. London, 1835."

	Bristol.	Leeds.	Norwich.	Total in the 3 Hospitals.
Under 10 years of age -	136	83	281	500
Between 10 and 20 - -	65	21	106	192
20 and 30 -	35	21	48	104
30 and 40 -	34	12	48	94
40 and 50 -	37	28	47	112
50 and 60 -	28	21	96	145
60 and 70 -	18	9	70	97
70 and 80 -	2	2	8	12
	355	197	704	1256

Consisting of: — Males, - - 1205; Females - - 51

Urine in disease may not only show a tendency to deposit matters of an insoluble character in the form of urinary deposits or calculi, but it may also contain in solution an excess or deficiency of any one or more of its normal constituents. There may likewise be present in solution matters altogether foreign to the healthy constitution of the fluid. The urine in disease may then, so far as its dissolved matters are concerned, be considered in two points of view, viz. 1. Excess or deficiency of normal constituents; 2. Presence of matters not existing in healthy urine.

I shall proceed to notice the state of the urine in those forms of disease in which it has received attention, and shall quote from the work of Franz Simon, who not only laboured long and well on the subject, but collected much valuable information relating to it. Before doing this, however, I must notice the ingenious attempt made by Becquerel to classify all diseased conditions of urine under four heads, viz. 1. Febrile urine; 2. Anæmic urine; 3. Alkaline urine; 4. Urine but slightly varying from the conditions of health.

I will shortly notice the principal characters of these four varieties.

1. *Febrile urine.* — *α. Febrile urine, strictly speaking.*—The proportion of water passed in the twenty-four hours less than in health. Solid matters slightly diminished in proportion. Urea and inorganic salts deficient. Uric acid increased in proportion. Colour high. Specific gravity above the normal standard. Often turbid from lithates. Sometimes contain albumen.

This latter statement of Becquerel's must be received with some reservation. Thus I have several times known a deposit produced in urine in adynamic forms of fever on the addition of nitric acid, which proved, on examination, to be lithic acid and not albumen.

The following are the conditions in which, according to Becquerel, the urine assumes the febrile character; viz., in chronic and acute inflammations; in diseases of the liver, heart, and lungs; in hæmorrhages, and in organic degenerations of organs resulting from fever or long functional derangement.

β. Febrile urine, with debility. — The proportion of water diminished. Specific gravity less than in *α*. Solid matters also less in the twenty-four hours. Uric acid in normal proportion. All other constituents *absolutely* but not *relatively* diminished. This urine is then less concentrated than that of health. It is deeply coloured, often turbid from deposit of uric acid. It occurs in adynamic fevers.

γ. Febrile urine containing the natural proportion of water. — Urea and fixed salts diminished in proportion. Uric acid and other organic matters normal. Specific gravity low. Colour deep. No sediment.

2. *Anæmic urine.* — *α. True anæmic urine.*— Water in the twenty-four hours nearly normal. Solids discharged much less than in health. Urea, uric acid, and fixed salts diminished. Other organic matters decreased in *slighter degree* than the above. Specific gravity low. Colour light. No sediment.

β. — Concentrated anæmic urine.—Water in twenty-four hours diminished, although the solids are then *relatively* increased, still they are *absolutely* diminished. Urea, uric acid, and fixed salts especially diminished. Other organic matters less so. Urine of livid or greenish tint.

3. *Alkaline urine.*—Distinguished by alkaline reaction on test paper. Odour ammoniacal: occurs in acute and chronic nephritis, diseases of the bladder with secretion of pus, and in certain cerebral diseases; occasionally in the "morbus Brightii."

4. *Urine nearly normal.* — Nearly that of health. Occurs in mild disorders unaccompanied by fever.

With respect to this classification of Becquerel, it may be observed that the heads of arrangement by no means embrace all the forms of diseased urine met with in practice, —an end, indeed, which will scarcely be compassed by any attempts of the kind. There appears no advantage in making such classifications; and indeed much evil must result from the necessary endeavour which will be made in such a table to place diseases under headings which either imperfectly or incorrectly express their real character. The table, however, is of some value, as showing the *general* results obtained in fevers and in anæmia; but further than this the student need not regard it.

The following introductory remarks by Franz Simon are extremely valuable, and will well repay the reader for the trouble taken in their careful perusal. I transcribe them from Dr. Day's translation for the Sydenham Society: —

"In inflammatory affections, and in those diseases which are accompanied by that form of fever which is termed sthenic or synochal, the urine differs greatly in its properties from normal urine. In speaking of the probable cause of the changed constitution of the blood in the phlogoses, I showed that it is not to be referred to the diseased organ, but to the reaction which manifests itself throughout the vascular system. If the change in the constitution of the blood bears an accurate and inseparable relation to the fever, there can be no doubt that the change in the constitution of the urine must be in relation to the same cause; for the urine is separated from the blood, and was previously an integral constituent of it: and because, further, every alteration in the constitution of the blood must involve corresponding changes in the secretions and excretions, and more especially in the urine. Since like effects follow like causes, and since in inflammatory affections the vascular system similarly participates in the disturbance, we may assume *à priori* that similar changes will occur in the urine,—a point confirmed by experience.

"The urine discharged during inflammations is usually termed febrile urine. There is no objection to this term, since the cause of the change in the urine must be sought for in the fever. I shall not, however, introduce the term 'febrile urine' here, since it is more than probable that the changes in the composition of the urine vary according as the character of the fever is synochal or torpid.

"My analyses show, in fact, that the relative proportions of urea in fevers of a torpid and of a synochal character are different; and although the analyses are not yet sufficiently numerous to establish the difference with certainty, it still appears to me to be a point of sufficient importance to demand attention, and one that should be carefully worked out. In order to take a correct view of the composition of the urine, we must bear in mind the composition of the blood, the reaction of the vascular system, and the diet, since the mixture of the proximate constituents is dependent upon these circumstances.

"The following are the general characteristics of the urine in inflammatory affections. It is darker than usual, and of a yellow, brown, or reddish-brown tint; it has an acid reaction, and is generally of a high specific gravity. With respect to its most important constituents, the urea is either absolutely increased, or is at the ordinary physiological average, or may be a little below it; the uric acid is always absolutely increased, and so are the extractive matters, especially the alcoholic extract. The salts are always absolutely diminished, especially the chloride of sodium. The sulphates, on the other hand, either approximate to the physiological average, or are not far below it.

"Assuming as the mean of numerous analyses, that the urea constitutes 39 per cent. of the solid residue of normal urine, I have found it as high as 46·8 in inflammatory affections. (In abdominal typhus, with a quick small pulse, I have seen it as low as 22.)

"The physiological average of uric acid may be placed at 1·5 per cent. of the solid residue; in the phlogoses I have observed it amount to nearly 3 per cent., and Becquerel even found it rise as high as 5·9 per cent. The quantity of extractive matter, &c., which in normal urine amounts to 23·5 per cent. of the solid residue, rises in inflammations to 43 per cent. The fixed salts, which in healthy urine constitute about 25 per cent. of the solid residue, diminish here to 12 per cent. The sulphate of potash, which in healthy urine forms about 10 per cent. of the solid residue, I found to vary in inflammation between 7 and 9 per cent.

"The composition of the urine becomes changed if much blood is abstracted during the inflammation. It becomes clearer, specifically lighter, and the amount of urea decreases absolutely and relatively.

"At the height of the inflammation, or (perhaps it would be better to say) at the time when the fever puts on the synochal type most strongly, the urine is usually clear and deeply coloured; it subsequently forms a sediment of a yellow or red colour, composed of uric acid and urates."

I shall now proceed to describe the state of the urine as it is observed in different diseases.

Pericarditis.—A man aged 36. Acute pericarditis; pulse 108, full, and hard; urine clear, deep red colour; specific gravity 1023·5; indications of albumen *by heat.* Analysis showed:—

Water	937·50
Solid residue	62·50
Urea	29·30
Uric acid	1·50
Extractive matters	22·70
Earthy phosphates	0·55
Sulphate of potash	4·89
Phosphate of soda	0·56
Chloride of sodium, and carbonate of soda	1·40

In the above case, after a large quantity of blood had been drawn, the urine changed as follows. Colour, that of health; acid reaction; devoid of albumen; specific gravity 1018. Its composition was now,—

Water	960·10
Solid residue	39·90
Urea	17·50
Uric acid	0·99
Extractive matters	15·10
Fixed salts	3·65

The first of these analyses is that of inflammatory urine. The second shows the effects of the copious bleedings in reducing the excretion nearer to the normal standard.

With respect to the presence of albumen in the urine in this and other inflammatory affections unconnected with disease of the kidneys, there is in my mind no doubt whatever that the opinion is founded in error. There is no institution in the world at which the question has been so thoroughly investigated as at Guy's Hospital; and our daily experience still confirms the opinions arrived at by Dr. Bright in his first experiments. It will be observed that the test of heat (a most inefficient one in itself) is alone referred to in the above-described case; and I have little doubt the precipitate produced was composed of phosphate of lime, a common source of fallacy which I pointed out some years ago in connection with this subject.*

Phlebitis Uterina.

The following is a description, by F. Simon' of specimens of urine in this disease. 1. Colour dark; reaction acid; deposit of uric acid and urate of ammonia. 2. Colour dark; alkaline reaction; ammoniacal odour; deposit dirty yellow in colour, composed of mucus, ammoniaco-magnesian phosphate, amorphous precipitate of phosphate of lime, and urate of ammonia.

Meningitis.

The urine in this disease assumes the ordinary inflammatory type. It is described as dark red, scanty (8 to 9 fluid ounces in the twenty-four hours), strongly acid; specific gravity high. According to Becquerel, the mean of four cases was 1025·2. Deposit of uric acid, which, if not present spontaneously, is immediately produced by the addition of nitric acid.

Encephalitis.

Urine much the same as in meningitis; sometimes a sediment. Spec. gravity, 1020·2.

Observations have been made by several foreign writers on the state of the urine in insanity. Drs. Sutherland and Rigby have also paid some attention to the subject. It appears to be generally alkaline, and to contain much ammonia in these cases; the whole subject, however, needs further and careful investigation. Dr. Bence Jones states, that in acute inflammation of the brain there is an increase in the total amount of phosphates excreted in the urine.

Delirium Tremens.

In this disease the urine is said to present the general features of the inflammatory type.

Dr. Bence Jones states, that in delirium tremens the phosphates are decreased in quantity in the urine, provided no food is taken. If food be taken, this diminution is not observed.

Myelitis.

In this disease the urine is of much the same character as in inflammation of the brain, viz. red, acid, thick, and containing a sediment. Cases are, however, recorded by Becquerel, in which the urine did not greatly vary from the natural standard. There appears no excessive excretion of the phosphates in this disease, according to Dr. Jones's experiments.

Bronchitis.

All that we gather worthy of notice from the detailed examinations of Becquerel in respect to the state of the urine in this disease is, that it occasionally contains albumen. This may perhaps sometimes happen when great obstruction to the circulation of blood through the lungs has existed for any length of time. In by far the greater number of cases, however, no indication of this kind is found, unless the kidneys be predisposed to such form of disease as favours the effusion of serum.

Pneumonia.

In pneumonia the urea excreted is less than in health; the uric acid is increased, the salts diminished, and the extractive matters increased, and more especially the alcoholic extract.

The following are comparative analyses of the solid matters in 100 parts:—

	Becquerel.	Simon.		Urine of health.
Urea - -	- 37·6	39·0	37·2	39·0
Uric acid -	- 2·0	1·7	2·8	1·5
Fixed salts	- 14·0	18·3	14·0	25·8
Extractives	- 45·4	40·0	37·0	23·6
Sulphate of potassa		9		10·3

During the resolution of pneumonia, Simon and Schönlein have observed that a deposit occurs in the urine composed of the monobasic ammoniaco-magnesian phosphate. Uric acid was also thrown down on the addition of acids. This latter reaction, however, is not peculiar to this disease, I having myself often observed it in low forms of fever and also in small-pox. Heller relates the case of a boy in which the urine had the odour of hydrosulphate of ammonia, and deposited urate of soda.

Pleuritis.

In this disease the urine in general exhibits much the same characters as in pneumonia.

Empyema.

In cases of empyema the urine has been observed to contain pus by Schönlein and Simon. The empyema gradually disappeared, the urine containing albumen, and the deposit, when examined, showing the ordinary pus corpuscles.

Hepatitis.

In hepatitis the urine is extremely deficient in urea, according to Rose, who in one case believed it absent. Henry agrees in this opinion; and Coindet states that, instead of urea, the urine contains a substance resembling bilin. Simon and Becquerel, however, differ from Rose and Henry, and mention a case of hepatitis in which urea was excreted in excess.

Nephritis.

In this disease, when it assumes the acute character, the urine is often bloody and very acid, and deposits the uric acid crystalline deposit. In arthritic nephritis the quantity of the uric acid crystals is sometimes extremely great. In a case mentioned by Schönlein the sediment occupied half the volume of the urine.

Chronic Nephritis, Albuminous Nephritis, Morbus Brightii.

In the morbus Brightii the urine contains abundance of albumen. Blood is occasionally observed in the early stages. It is generally acid, far less frequently alkaline, and occasion-

* For the proper method of examining the urine in order to determine the presence or absence of albumen, I beg to refer to my work on Diseases of the Kidney connected with albuminous urine.

ally neutral. Its specific gravity is nearly always lower than that of health. The uric acid is usually in very small proportion, and sometimes altogether absent. This is not, however, always the case; and I have sometimes seen the lithic acid in excess existing as a deposit. Simon believes albumen not unfrequently present in diseases quite unconnected with affections of the kidneys. His facts, however, are not satisfactorily stated, and I believe him to have been greatly mistaken in this opinion. In connection with the morbus Brightii, we have to notice two substances which, according to Heller, are often present as deposits in that disease, viz. uroglaucin and urrhodin. These are colouring matters, derived by oxidation from uroxanthin, or a yellow colouring matter of urine, which exists only in small proportion in healthy urine, but which is greatly increased in Bright's disease. The deposits observed in the morbus Brightii consist of the casts of the urinary tubules of the kidney — epithelium of two kinds, viz. spheroidal and pavement epithelium. (*Vide* woodcut of urinary deposits, *fig.* 799.)

Cystitis.

The urine in this disease is alkaline, the alkalinity increasing rapidly after the urine is voided, owing to the formation of carbonate of ammonia. Mucus and pus are present in quantity. Albumen can always be detected in solution when the pus corpuscles are present in the deposit. As cure is effecting, this albumen is found to decrease in proportion as the pus corpucles disappear.

Typhus.

In typhus the urine shows no great variation from the normal standard, so far as specific gravity and amount of solid constituents is concerned. The urea is generally in deficient proportion, the uric acid increased. The salts are much diminished. During the progress of typhus, the urine very generally becomes alkaline. Becquerel and Andral have made many experiments on the state of the urine both in typhus and typhoid fevers. They both have met with a large number of cases in which it was precipitable by nitric acid; this is quite in accordance with my own observations; the precipitate, however, is lithic acid, and not albumen.

Scherer found, like former observers, that the salts were much decreased in the urine of typhus, and that there was always an excess of uric acid.

The following analyses are worthy of note. They were made by Scherer at the 9th, 12th, and 15th day of a slow nervous fever, which occurred in the person of a woman aged thirty-eight years.

9th Day.

Water - - - - - -	945·48
Urea - - - - - -	8·60
Uric acid - - - - -	0·60
Alcoholic extractive - -	27·50
Watery ditto - - - - -	7·40
Albumen - - - -	1·80
Fixed salts soluble in water -	6·20
Earthy phosphates - - -	2·30

12th Day.

Water - - - - - -	951·26
Urea - - - - - -	10·40
Uric acid - - - - -	0·70
Alcoholic extractive - -	21·80
Watery ditto - - -	7·90
Albumen - - - - -	1·00
Fixed salts soluble in water -	5·30
Earthy phosphates - - -	1·20

15th Day.

Water - - - - - -	959·29
Urea - - - - - -	11·40
Uric acid - - - - -	0·80
Alcoholic extract - - -	15·70
Watery ditto - - - - -	6·20
Albumen and mucus - -	0·90
Fixed salts soluble in water -	4·50
Earthy phosphates - -	0·60

It will be observed that, as the disease progressed, the urea increased, while the extractive matters diminished. The "salts soluble in water" also diminished in quantity.

Intermittent Fever.

L'Héritier has made analyses of the urine in this disease, and has drawn up the following table, which represents its composition in the different stages, as deduced from a mean obtained from twelve cases.

	Cold Stage.	Hot Stage.	Sweating Stage.
Specific gravity -	1017·330	1020·304	1022·820
Water -	967·520	964·680	961·845
Urea -	9·845	9·015	7·624
Uric acid -	0·660	0·980	1·029
Salts and organic matter -	21·975	25·325	29·502

Notwithstanding the variations from the natural standard shown by the above table, it often happens that the urine in agues differs but little from that of health in every stage of the disease.

Cholera.

In this disease the urine is often altogether suppressed. When it can be collected in any quantity, its specific gravity is generally below the natural standard, and it has only a feeble acid reaction. Albumen is very often to be found it it. The urea is below the standard of health. Vogel states that the urine, in a case of this disease which he examined, was entirely wanting in the salts of lime and magnesia, and that the chloride of sodium was deficient. The sulphates, however, were in larger proportion than in health. Albumen and biliary colouring matter could be detected by the appropriate tests.

Rheumatism.

In this disease the urine shows the usual appearances of the inflammatory type, according to Becquerel. Oxalate of lime not unfrequently exists as a deposit.

Phthisis.

In this disease the principal feature observed in the urine is the increase in the quantity of uric acid. One analysis gave as much as 2·40 of this acid in 1000 parts of urine.

Struma.

In struma, generally speaking, the urine is deficient in urea and uric acid. The phosphates are often excreted in excess, and there is a tendency to the deposit of oxalate of lime. In mollities ossium and rachitis the earthy phosphates are excreted in very large quantity, the alkaline salts are increased, and the urea and uric acid diminished in proportion. The analyses which showed the above results were made on the urine of children, which always contains less urea and salts than that of adults.

The following is an analysis, by Marchand, of the urine of a child suffering from mollities ossium. It was acid.

Water - - - - - -	938·2
Urea - - - - - -	27·3
Uric acid - - - - -	0·9
Lactic acid and lactates - -	14 2
Phosphates of lime and magnesia	5·7
Other constituents (loss) - -	13·7

Diabetes Mellitus.

The urine in this disease contains a sugar which may be regarded as identical with sugar of grapes. It is generally of very high specific gravity, varying from the highest specific gravity observed in health to 1055 or even 1060.

Schönlein has an opinion that in the first stages of diabetes there is albumen in the urine, and that this becomes replaced by sugar. This opinion I scarcely can believe correct. The fact, indeed, could not well have escaped my notice, my attention having been particularly directed to the study of albuminaria for some years past. The experiments of Kant have shown that urea is generally excreted in diabetes mellitus to the same amount as in health in the twenty-four hours. During the progress of the disease I have several times observed the whole of the sugar suddenly disappear from the urine, and its place supplied by an enormous excretion of urea. I at first was inclined to regard this as a favourable indication, but experience has not confirmed that belief. Uric acid is not uncommonly present in considerable quantity, and this I believe to be a favourable indication in diabetes. Simon has shown that the absolute quantity of urea excreted in twenty-four hours is occasionally diminished; but the general rule is that the quantity approaches that of health. Caseous matter is sometimes found in diabetic urine, and, when present, it excites rapid fermentation immediately after the urine is voided.

Bouchardat has described a form of sugar which occasionally exists in diabetes, which is insipid, but which corresponds in every other respect with the sweet sugar. Simon says he once met with it.

Lehmann, Ambrosiani, Müller, and Simon have observed the presence of hippuric acid in diabetic urine.

Diabetes Insipidus.

In this disease the urine contains an excess of water, and varies in specific gravity from 1001 to 1006. The urea, if regarded in proportion to the other solid matters excreted, is excessive in quantity, but the proportion discharged during the twenty-four hours is generally far below that of health.

This excessive discharge of urea, as compared with the other solids, may be accompanied by a less discharge of water than that which is generally found to accompany it. Then the urine attains a specific gravity approaching that of health, and sometimes even exceeding it. Chemically, these two conditions so nearly approach, as scarcely to need division. Pathologically considered, however, the latter is the more serious form of disease, and is believed by some to be not an unfrequent forerunner of diabetes mellitus.

Diabetes Chylosus.

This disease is characterised by the discharge of chyle in the urine. It is quite milky in appearance. A specimen I examined some few years ago yielded the following results:

Specific gravity 1021.

Acid in slight degree only.

Milkiness, not changed from subsidence by standing.

Agitated with ether the urine was cleared, and the ethereal solution, which then floated above, contained a fat, yielding an alkaline ash on incineration. This fat was not saponifiable by boiling with a solution of potassa. The urine cleared from the fat coagulated by boiling, and also on the addition of nitric acid.

Jaundice.

The elements of bile exist in the urine in cases of jaundice. Simon has published the following result, obtained from the urine of a female, aged twenty, suffering from inflammatory icterus.

The urine was brownish red, and of specific gravity 1020, and very acid.

Water - - - - - -	954·50
Urea - - - - - -	12·34
Uric acid, with biliphæin -	2·90
Alcoholic extractive - -	4·35
Spirituous ditto - - -	5·29
Aqueous ditto, with mucus and bile pigment - -	5·14
Biliary resin - - - -	1·45
Biliverdin - - - - -	1·08
Earthy phosphates - - -	3·14
Chloride of sodium and lactate of soda - - -	2·61
Alkaline phosphates and sulphates, with traces of chloride of sodium - -	3·90

The urea is here below the normal standard; the uric acid increased.

Scherer examined urine obtained from a person labouring under long-continued icterus, dependent on chronic inflammation of the hepatic structure. On emission this urine was clear, yellow, and perfectly neutral: it subsequently became acid, and deposited uric acid and bile pigment. This acidity Scherer believes was owing to the development of lactic acid.

The specific gravity of the specimen was 1018; 1000 parts yielded 4·3 of urea only, and as much as 1·8 of uric acid. Silica was also found in this urine.

Urine of Pregnancy.

The urine of pregnant women often contains a peculiar substance, to which the name of kystein has been given. It appears as a white scum when the urine has stood some hours. I have frequently found this substance in urine at the third and fourth months of gestation, and have no doubt that its appearance is closely connected with the phenomenon of the secretion of milk. In several instances I succeeded in detecting distinct milk globules in such urine.

Foreign Substances in the Urine.

Medicines, and substances taken for food, are occasionally found in the urine. Some of these, however, undergo changes in the organism before they are excreted by the kidneys.

Simon has classified these bodies; and I shall here enumerate them according to his arrangement.

Inorganic non-metallic bodies. — Iodine, bromine, chlorine, sulphur *, iodide of potassium, alkaline borates, silicates, chlorates, and carbonates, chloride of barium, ferridcyanide of potassium, sulphocyanide of potassium. The ferridcyanide was converted, however, into the ferrocyanide in the system.

Metallic substances. — Arsenic, antimony, iron, nickel, gold, silver, tin, lead, bismuth, copper, and manganese. I have sought in vain for mercury in the urine. Lehmann and L'Héritier have also failed to find it where it has been largely exhibited. Several chemists, however, declare they have detected it.

Inorganic acids. — Nitric †, hydrochloric, and sulphuric.

Organic acids. — Oxalic, citric, malic, tartaric, succinic, gallic, and acetic.

Pereira has succeeded in detecting meconic acid in the urine of animals poisoned by opium.

Vegetable bases. — Quina, morphia.

Indifferent organic substances. — Colouring matters of indigo, gamboge, rhubarb, red beetroot, madder, logwood, mulberries, black cherries; odorous principles of valerian, assafœtida, garlic, castoreum, saffron, turpentine.

Liebig and Wöhler both state that alcohol cannot be detected in the urine. Percy, however, has proved that it can. Dr. Wright has corroborated Percy's experiments, and obtained alcohol by the same plan of analysis.

Lehmann and others sought unsuccessfully for the following substances in the urine: viz., salicin, phloridzin, caffein, theobromin, asparagin, and amygdalin. These substances probably undergo changes in the organism.

Lehmann has shown that salicin becomes converted into salicylous acid; this was taken up by ether with the oxide of omichmyle. The addition of nitrate of iron produced the fine violet colour characteristic of salicylous acid. Hippuric acid and oxalate of lime were also produced.

Phloridzin is converted into oxalic and hippuric acids during its passage through the organism, according to Lehmann.

For the Bibliography reference is made to the works of Berzelius, Prout, Simon, Liebig, Dumas, Lehmann, on Animal Chemistry, and to those quoted in the foot notes.

(*G. Owen Rees.*)

VARIETIES OF MANKIND.—Under this head it is intended to give a general account of the distinctive characters, — structural, physiological, and psychological — of the principal Races of Men; and to inquire into the nature and degree of their mutual affinity. Before entering upon these subjects, however, it will be desirable, in the first place, to set forth the most important characters by which Man, under whatever form, is distinguished from the Mammalia which approach most nearly to him; and, secondly, to lay a foundation in the recognised principles of natural history and physiology, for a true appreciation of the characters which serve to distinguish *species* from each other, as contrasted with those which may be presented by *varieties*, whose original stock is known, or believed, to have been identical.

I. Distinctive Characteristics of Man.

By Cuvier and nearly all modern zoologists, the various races of mankind are included under one genus, *Homo;* and this genus takes rank, in the classification of Mammalia, as a distinct order, Bimana, of which it is the sole representative. Of all the characters which distinguish Man from the inferior Mammalia, the possession of *two hands* is doubtless the most easily recognised, and at the same time the most intimately related to the general organisation of the body; and there is none, therefore, which could be more appropriately selected as the basis of a distinctive designation for this order. At first sight it might be considered that the possession of only *two* hands, whilst Apes and Monkeys and their allies are designated as possessing *four*, is a character of inferiority; but such is not really the case; for none

* This, if exhibited in combination in sulphurets, is excreted as sulphate of the base.

† Dr. Bence Jones believes that nitric acid is commonly present in healthy urine, and appears as the result of the oxidation of nitrogenised food.

of these four hands are adapted to the variety of actions of which those of man are capable, and they are all in some degree required for support; so that whilst in the higher forms of the Quadrumanous order, the extremities present a certain approximation in structure to those of man, in the lower they gradually assimilate to the ordinary quadrupedal type. "That," says Cuvier, "which constitutes the *hand*, properly so called, is the faculty of opposing the thumb to the other fingers, so as to seize upon the most minute objects; a faculty which is carried to its highest degree of perfection in Man, in whom the whole anterior extremity is free, and can be employed in prehension." The peculiar prehensile power possessed by man is chiefly dependent upon the size and power of the thumb; which is more developed in Man than it is in the highest apes. The thumb of the human hand can be brought into exact opposition to the extremities of all the fingers, whether singly or in combination; whilst in those Quadrumana which most nearly approach man, the thumb is so short, and the fingers so much elongated, that their tips can scarcely be brought into opposition; and the thumb and fingers are so weak, that they can never be opposed to each other with any degree of force. Hence, although admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, &c., the extremities of the Quadrumana can neither seize very minute objects with such precision, nor support large ones with such firmness, as are essential to the dexterous performance of a variety of operations, for which the hand of Man is admirably adapted. There is much truth, then, in Sir C. Bell's remark, that "we ought to define the hand as belonging exclusively to man." There is in him, what we observe in none of the Mammalia which approach him in other respects, a complete distinction in the functional character of the anterior and posterior extremities; the former being adapted for prehension alone, and the latter for support and progression alone; and thus each function is performed in a much higher degree of perfection, than it can be when two such opposite purposes have to be united. For not only is the hand of man a much more perfect prehensile instrument than that of the orang or chimpanzee, but his foot is a much more perfect organ of support and progression than theirs, being adapted to maintain his body in an erect position, alike during rest and whilst in motion, — an attitude which even the most anthropoid apes can only sustain for a short time, and with an obvious effort. The arm of the higher apes has as wide a range of motion as that of man, so far as its articulation is concerned; but it is only when the animal is in the erect attitude, that the limb can have free play. Thus the structure of the whole frame must be conformable to that of the hand, in the way that we find it to be in man, in order that this organ may be advantageously applied to the purposes which it is adapted to perform. But it cannot be said with truth (as some have maintained) that Man owes his superiority to his hand alone; for without the mind by which it is directed, and the senses by which its operations are guided, it would be a comparatively valueless instrument. Man's elevated position is due to the superiority of his mind and of its material instruments conjointly; for if destitute of either, the human race must be speedily extinguished altogether, or reduced to a very subordinate grade of existence.

The next series of characters to be considered, are those by which man is adapted to the erect attitude. On examining his *cranium*, we remark that the occipital condyles are so placed, that a perpendicular dropped from the centre of gravity of the head would nearly fall between them, so as to be within the base on which it rests upon the spinal column. The foramen magnum is not placed in the centre of the skull, but just behind it; so that the greater specific gravity of the posterior part of the head, which is entirely filled with solid matter, is compensated by the greater length of the anterior part, which contains many cavities. There is, indeed, a little over-compensation, which gives a slight preponderance to the front of the head, so that it drops forwards and downwards, when all the muscles are relaxed; but the muscles which are attached to the occiput are larger and far more numerous than those in front of the condyles, so that they are evidently intended to counteract this disposition; and we find, accordingly, that we can keep up the head for a whole day, with so slight and involuntary effort, that no fatigue is produced by it. Moreover, the plane of the foramen magnum, and the surfaces of the condyles, have a nearly horizontal direction when the head is upright; and thus the weight of the skull is laid vertically upon the top of the vertebral column. If these arrangements be compared with those which prevail in other Mammalia, it will be found that the foramen and condyles are placed in the latter much nearer the back of the head, and that their plane is more oblique. Thus, whilst the foramen magnum is situated, in Man, just behind the centre of the base of the skull, it is found in the Chimpanzee and Orang to occupy the middle of the posterior third; and as we descend through the scale of Mammalia, we observe that it gradually approaches the back of the skull, and at last comes nearly into the line of its longest diameter, as we see in the Horse. So the angle of inclination which the condyles make with the horizontal is very small in Man, but rises in the Orang to 37°; whilst in the Horse their plane is vertical, making the angle 90°. If, therefore, the natural posture of man had been horizontal, the plane of his condyles would be brought, like that of the horse, into the vertical position; and the head, instead of being nearly balanced upon the summit of the vertebral column, would hang at the end of the neck, so that its whole weight would have to be supported by some external and constantly-acting power. But for this there is neither in the skeleton, the ligamentous apparatus, nor the muscular system of Man, any adequate provision; so that in any other than the vertical position, his head, which is relatively heavier than that of most Mammalia, would be supported with more difficulty and effort than it is in any other animal.

The position of the *face* immediately beneath the anterior portion of the cranial cavity, so that its front is nearly in the same plane as the forehead, is peculiarly characteristic of Man; for the crania of the Chimpanzee and Orang, which approach most nearly to that of man, are entirely posterior to, not above, the face (see *figs.* 800—802.). It should be remarked that in the young ape, there is a much greater resemblance to man in this respect, than there is in the adult; for it is at the time of the second dentition, that the muzzle of the ape acquires its peculiar elongation and consequent projection in front of the forehead; and the whole cast of the features is altered at the same time, so as to approximate much more closely to that of the lower Quadrumana than would have been thought likely from the inspection of the young animal only. This projection of the muzzle, taken in connection with the obliquity of the condyles, is another evidence of want of adaptation to the erect posture; whilst the want of prominence in the face of Man shows that none but the erect position can be natural to him. For supposing that with a head formed and situated as at present, he were to move upon all fours, his face would be brought into a plane parallel with the ground; so that as painful an effort would be required to examine with the eyes an object placed in front of the body, as is now necessary to keep the eyes fixed on the zenith; the nose would then be almost incapacitated for receiving any other odorous emanations, than those proceeding from the earth or from the body itself; and the mouth could not touch the ground, without bringing the forehead and chin also in contact with it. The obliquity of the condyles in the Quadrumana enables them without much difficulty to adapt the inclination of their heads either to the horizontal or to the erect posture; but the natural position, in the highest among them, is unquestionably one in which the spinal column is inclined, the body being partially thrown forwards, so as to rest upon the anterior extremities; and in this position, the face is directed forwards without any effort.

The *vertebral column* in Man, although not absolutely straight, has its curves so arranged, that when the body is in the erect posture, a vertical line from its summit would fall exactly on the centre of its base. It increases considerably in size in the lumbar region, so as to be altogether somewhat pyramidal in its form. The lumbar portion, in the chimpanzee and orang, is by no means of the same proportional strength, and contains but four vertebræ instead of five. The processes for the attachment of the dorso-spinal muscles to this part, are peculiarly large and strong in man; and this arrangement is obviously adapted to overcome the tendency, which the weight of the trunk in front of the column would have to draw it forwards and downwards. On the other hand, the spinous processes of the cervical and dorsal vertebræ, which in other Mammalia are large and strong, for the attachment of the ligaments and muscles that support the head, have comparatively little prominence in man, whose head is balanced upon the summit of the column.

The base of the human vertebral column is placed on a sacrum of greater proportional breadth than that of any other animal; this sacrum is fixed between two widely expanded ilia; and the whole *pelvis* is thus peculiarly broad. In this manner the femoral articulations are thrown very far apart, so as to give a wide basis of support; and by the oblique direction of the axis of the pelvis, the weight of the body is transmitted almost vertically from the top of the sacrum to the upper part of the thigh bones. The pelvis of the anthropoid apes is very differently constructed. That of the orang, for example, is much longer and narrower; its alæ extend upwards rather than outwards, so that the space between the lowest ribs and the crest of the iliac bones is much less than in man; their surfaces are nearly parallel to that of the sacrum, which is itself longer and narrower; and the axis of the pelvis is nearly parallel with that of the vertebral column. The position of the human femur, in which its head is most securely retained in its deep acetabulum, is that which it has when supporting the body in the erect attitude; in the chimpanzee and orang, its analogous position is at an oblique angle to the long axis of the pelvis, so that the body leans forwards in front of it; in many of the four-footed Mammalia, as the elephant, it makes a right angle with the vertebral column; and in several others, as the horse, ox, &c., the angle which it makes with the axis of the pelvis and vertebral column is acute. In this respect, then, the skeleton of man presents an adaptation to the erect posture, which is exhibited by that of no other mammal.

The *lower extremities* of Man are remarkable for their length, which is proportionally greater than that which we find in any other mammalia, excepting the kangaroo and a few other leaping animals. The chief difference in their proportional length, between man and the semi-erect apes, is seen in the thigh; and from the relative length of this part in him, and the comparative shortness of his anterior extremities, it happens that the hands of Man, when he is standing erect, only reach to the middle of his thighs, whilst in the Chimpanzee they hang on a level with the knees, and in the Orang they descend to the ancles. The human femur is distinguished by its form and position, as well as by its length. The obliquity of its neck still further increases the breadth of the hips; whilst it causes the lower extremities of the femora to be somewhat obliquely directed towards each other, so that the knees are brought more nearly into the line of the axis of the body. This arrangement is of the greatest importance in facilitating the purely *biped* progression of Man, in which the entire weight of the body must be alternately supported upon each limb; for if the knees had been kept further apart, the whole body must have been swung from side to side at each step, so as to bring the centre of gravity over each tibia, — as is seen, to a certain extent, in the female sex, whose walk, owing to the greater breadth of the pelvis, and the separation between the knees, is less steady than that of the male. There is a very marked contrast between the knee-joint of Man, and that of even the highest Apes. In the former the opposed extremities of the femur and tibia are so expanded as to present a very broad articulating surface; and the internal condyle of the femur being the longer of the two, they are in the same horizontal plane in the usual oblique position of that bone; so that by this arrangement the whole weight of the body, in its erect posture, falls vertically on the head of the tibia, when the joint is in the firmest position in which it can be placed. The knee-joint of the Orang, on the other hand, is comparatively deficient in extent of articulating surface; and its whole conformation indicates that it is not intended to serve as more than a partial support. The human foot is, in proportion to the size of the whole body, larger, broader, and stronger than that of any other existing mammal, save the kangaroo. Its plane is directed at right angles to that of the leg; and its sole is concave, so that the whole weight of the body falls on the summit of an arch, of which the os calcis and the metatarsal bones form the two points of support. This arched form of the foot, and the habitual contact of the os calcis with the ground, are peculiar to Man alone. All the apes have the os calcis small, straight, and more or less raised from the ground, which they touch, when standing erect, with the outer side of the foot only; whilst in animals more remote from man, the os calcis is brought still more into the line of the tibia; and the foot being more elongated and narrowed, only the extremities of the toes come in contact with the ground. Hence Man is the only species of mammal which can stand on one leg. The points in which the feet of the anthropoid apes differ from his, all assimilate them to the manual type of conformation, and enable them to serve as more efficient prehensile organs, whilst they diminish their capacity to sustain the weight of the body when it simply rests upon them.

There is a considerable difference in the form of the *trunk*, between Man and most other mammalia; for his thorax is expanded laterally, and flattened in front, so as to prevent the centre of gravity from being carried too far forwards. His sternum is short and broad compared with that of quadrupeds generally; and there is consequently a considerable space between its lower extremity and the symphysis pubis, occupied solely by muscular parts, which would be quite inadequate to sustain the weight of the viscera, if the habitual position of the trunk had been horizontal. In these particulars, however, the most anthropoid Apes agree with Man.

Returning now to the *skull* for a more minute examination, and referring to the article QUADRUMANA for an account of the principal differences presented between the skulls of the ordinary Chimpanzee and Orang, and that of Man, we shall take as our standard of comparison the recently-discovered species of Chimpanzee, designated as the *Troglodytes gorilla*, whose cranium is considered by Prof. Owen to approach in some respects more nearly to that of man, than do either of the preceding. This species differs from the *T. niger* (*Simia troglodytes*, Vrolik) by its considerably greater dimensions, by the greater prominence of the supra-orbital ridges, the enormous development of the crest, which occupies the place of the sagittal suture, the greater strength of the zygomatic arches, and the greater size of the temporal fossa. For the more minute, but definite characters, on which the specific distinction is grounded, the description by Prof. Owen must be consulted.* The slightest glance at *figs.* 800, 801, 802. is sufficient to show how strongly marked are the features by which the skull of this Chimpanzee differs from that of even the most degraded of the Human family; but it will be advantageous to subjoin Prof. Owen's enumeration of the chief differences which are revealed by a careful anatomical survey. These are: —

"1. The smaller proportional size of the cranium.

"2. The more backward position of the foramen magnum, and its more oblique plane in relation to that of the base of the skull.

"3. The smaller relative size, and more backward position, of the occipital condyles.

"4. The longer basi-occipital, and broader, flatter, and lower supra-occipital.

"5. The longer basisphenoid, and shorter alisphenoids.

"6. The smaller size of the coalesced parietals, and their separation from the alisphenoids.

"7. The conversion of a greater part of the outer surface of the parietals into concavities or depressions for the lodgment of the temporal muscles, by reason of the bony crest developed from the line of the obliterated sagittal suture, and of the lambdoidal crest.

"8. The larger proportion of this crest and of the squamosal plate developed from the mastoid, and the smaller size of the proper mastoid processes.

"9. The smaller size of the vaginal and styliform processes, and the absence of the

* Transactions of the Zoological Society, vol. iii. p. 392. et seq.

styloid process, arising from the non-anchylosis of the stylo-hyal bone.

Fig. 800.

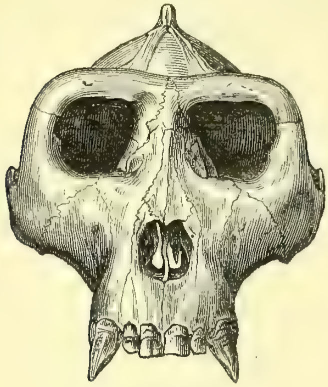


Fig. 801.

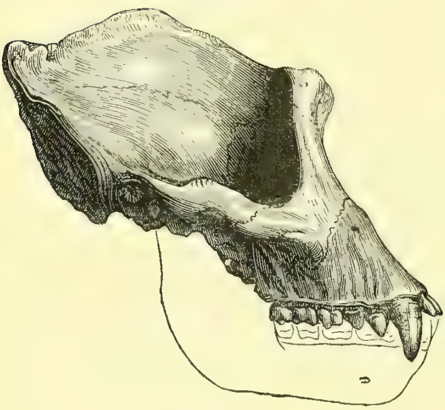
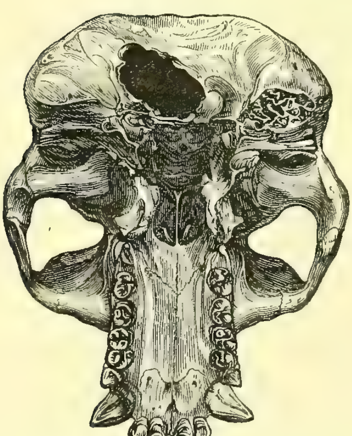


Fig. 802.



Front, side, and basal views of the skull of the Troglodytes gorilla. (*After Owen.*)

"10. The larger post-glenoid process, and the longer auditory process (tympanic bone), with their relative position, one behind, but not below, the other.

"11. The position of the stronger zygomata opposite the middle third of the basis cranii.

"12. The prominent supra-orbital ridge.

"13. The longer nasal bones, anchylosed together, and flattened at their lower half.

"14. The greater proportional size, and greater prominence of the upper and lower jaws.

"15. The longer osseous palate, and the median emargination of its posterior border.

"16. The parallelism of the alveoli of the molars and canine of one side, with those of the other.

"17. The diastema, or vacant place, in front of the socket of the canine in the upper jaw, and behind that socket in the lower jaw.

"18. The larger and more produced premaxillaries, the persistence of more or less of their sutures, showing the intervention of their upper extremities between the nasal and maxillary bones.

"19. The minor extent of connection of the lachrymal with the 'pars plana' of the æthmoid, or their separation by the junction of the orbital plate of the maxillary with that of the frontal behind the lachrymal.

"20. The depth of the olfactory fossa, and the absence or rudimental state of the crista galli.

"21. The squamosal, lambdoidal, alisphenoidal and pterygoid air-cells.

"22. The more prominent cusps of the molar teeth.

"23. The larger relative size, and more complex grinding surface of the last molar tooth in both jaws.

"24. The larger relative size of the premolars, especially of the first.

"25. The more complex implantation of the premolars by three roots, two external and one internal.

"26. The much larger and longer canines.

"27. The sexual distinction in the development of these teeth.

"28. The more sloping position of the crowns of the incisors.

"29. The broader and higher ascending ramus of the lower jaw.

"30. The total absence of the prominence of the symphysis forming the chin.

"In the form of the premaxillaries, and the earlier obliteration of their sutures," Prof. Owen continues, "the smaller chimpanzee more nearly resembles man than the great gorilla does; it seems also to deviate less through the minor development of the canine teeth, and of the parietal and sagittal crests; but it has been shown, in the comparison of the skulls of *Troglodytes gorilla* and *T. niger*, that the latter departs in more numerous and important particulars further from the human type."

Now, of the foregoing characters, some of those which constitute the most striking features in the cranium of the Chimpanzee, are those which must be admitted from analogy to be liable to variation under the influence of a change of habits, provided such change could be induced. Thus we find that in dogs, the general form of the cranium, and the sagittal crest, undergo considerable modification; the brain acquiring a very large size, in several of the domesticated races, at an early period of life; and the parietal bones being expanded over it so as to form a smooth dome, instead of rising up to meet in a vertical ridge. But the prominence of the supra-orbital ridge does not seem to be in any way connected with the relative development of the cerebrum and of the muscular system; and as Prof. Owen remarks, "We have no grounds from observation or experiment to believe the absence or the presence of a prominent supra-orbital ridge to be a modifiable character, or one to be gained or lost through the operation of external causes, inducing particular habits through successive generations of a species. It may be concluded, therefore, that such feeble indication of the supra-orbital ridge, aided by the expansion of the frontal sinuses, as exists in man, is as much a specific peculiarity of the human skull, in the present comparison, as the exaggeration or suppression of this ridge is respectively characteristic of the chimpanzees and orangs." The same may be said of nearly all the other distinctive characters which have been so minutely enumerated; for they serve to distinguish the great chimpanzee from *all* the varieties of the human race,—from the most degraded African, as well as from the most elevated European. The shape, size, and construction of the "premaxillary" bones ("inter-maxillaries" of the ordinary nomenclature) are peculiarly distinctive; for they not only differ from those of Man in their vastly greater proportional size, their greater prominence, and the longer persistence of their sutures, but also in their upward extension around the nostrils, so that they completely exclude the maxillary bones from their borders, and form the bases of support for the nasal bones (*fig.* 800.) It is to be remembered that the apparent deficiency of the inter-maxillary bone in the human subject is the result of its early coalescence with the maxillary; and that this coalescence may be prevented by an arrest of development, so that the two bones remain permanently distinct.*

Having dwelt thus fully on the distinctive features of the Osteology of Man, it will be sufficient to pass over his other peculiarities of conformation more cursorily, referring to the article QUADRUMANA for more minute details. In his *Myology*, the most characteristic difference is the much greater development of those muscles of the trunk and limbs, which contribute to the maintenance of the erect posture. Thus the gastrocnemii and the other muscles which tend to keep the leg erect upon the foot, form a much more prominent "calf" than is seen in any other animal. So, again, the extensors of the leg upon the thigh are much more powerful than the flexors; a character which is peculiar to man. The glutæi, by which the pelvis is kept erect upon the thigh, are of far greater size than is elsewhere seen. The superior power of the muscles tending to draw the head and spine backwards, has been already referred to. Among the differences in the attachment of individual muscles, we may notice that the flexor longus pollicis pedis proceeds in man to the great toe alone, on which the weight of the body is often supported; whilst it is attached in the chimpanzee and orang to the three middle toes. The latissimus dorsi of man is destitute of that prolongation attached to the olecranon, which is found in most of the lower Mammalia, and which exists even in the chimpanzee, probably giving assistance in its climbing movements. The larger size of the muscles of the thumb is, as might be expected, a characteristic of the hand of man, though the number of muscles by which that digit is moved is the same in the chimpanzee as in the human subject. The existence of the extensor digiti indicis, as a distinct muscle, however, is peculiar to man.

The *visceral* apparatus of Man presents very few characteristic peculiarities, by which it can be distinguished from that of the higher Quadrumana; among the most remarkable is the absence of the laryngeal pouches, which exist even in the chimpanzee and orang-outan, as dilatations of the laryngeal ventricles. Of the anatomy of the last-named animals in their *adult* condition, however, we know as yet too little, to enable its resemblance to that of man to be confidently pronounced upon.

The conformation of the *brain* of Man does not differ so much from that of the chimpanzee and orang, as the superiority of his mental endowments might have led us to anticipate. The following are the principal differences which it seems to present:—1. The mass of the entire brain is considerably larger in proportion to that of the body, and in proportion also to the diameter of the nerves which are connected with it. 2. In the external configuration of the cerebrum, we notice that the *posterior* lobes are more developed, so as to project further beyond the cerebellum than they do in any of the quadrumana; the convolutions are more numerous, and the sulci are deeper. 3. On examining the internal structure, it is found that the peripheral layer of grey matter is thicker, the corpus callosum extends further backwards, and the posterior cornua of the lateral ventricles are relatively longer and larger than they are in any Quadrumana. 4. The cerebellum, also, is proportionally larger. — The great size of the cranial portion of the skull in Man, as compared with the facial, produces a marked difference between his facial angle, and that of even the highest Quadrumana. According to Camper, who first

* A very definite account of the early embryonic state of the intermaxillary bone, is given by Dr. Leidy in the Proceedings of the Academy of the Natural Sciences of Philadelphia for 1848.

applied this method of measurement, the facial angle of the average of European skulls is 80°, whilst in the ideal heads of the Grecian gods it is increased to 90°; on the other hand, in the skull of a Kalmuck he found it to be 75°, and in that of a Negro only 70°; and applying the same system of measurement to the skulls of Apes, he found them to range from 64° to 60°. But these last measurements were all taken from young skulls, in which the forward extension of the jaws, which takes place on the second dentition, had not yet occurred. In the adult Chimpanzee, as we learn from the measurements of Prof. Owen, the facial angle is no more than 35°, and in the adult Orang only 30°; so that instead of the Negro being nearer to the Ape than to the European, as Camper's estimate would make him, the interval between the most degraded human races and the most elevated Quadrumana is vastly greater than between the highest and lowest forms of humanity. It must be borne in mind that the facial angle is so much affected by the degree of prominence of the jaws, that it can never afford any certain information concerning the elevation of the forehead and the capacity of the cranium; all that it can in any degree serve to indicate, is the relative proportion between the facial and cranial parts of the skull. The small size of the face of Man, compared with that of the cranium, is an indication that in him *the senses* are subordinated to the *intelligence*. Accordingly we find that he is surpassed by many of the lower animals in acuteness of sensibility to light, sound, &c.; but he stands preeminent in the power of comparing and judging of his sensations, and of drawing conclusions from them as to their objective sources. Moreover, although none of his senses are very acute in his natural state, they are all moderately so; and they are capable of being wonderfully improved by practice, when circumstances strongly call for their exercise. This seems especially the case with the tactile sense (see article Touch, p. 1177), of which man can make greater use than any other animal, in consequence of the entire freedom of his anterior extremities, although there are many which surpass him in their power of appreciating certain classes of tactile impressions. So, again, Man's nervo-muscular power is inferior to that of most other animals of his size; the full grown Orang, for example, surpasses him both in strength and agility; and the larger Chimpanzee, according to the statements of the negroes who have encountered it, is far more than a match for any single man, and is almost certain to destroy any human opponent when once within his grasp. The absence of any natural weapons of offence, and of direct means of defence, are remarkable characteristics of Man, and distinguish him not only from the lower Mammalia, but also from the most anthropoid Apes; in which it is obvious (both from their habits and general organisation) that the enormous canines have no relation to a carnivorous regimen, but are instruments of warfare. On those animals to which nature has denied weapons of attack, she has bestowed the means either of passive defence, of concealment, or of flight; in each of which Man is deficient. Yet, by his superior reason, he has not only been enabled to resist the attacks of other animals, but even to bring them into subjection to himself. His intellect can scarcely suggest the mechanism which his hands cannot frame; and he has devised and constructed arms more powerful than those which any other creature wields, and defences so secure as to defy the assaults of all but his fellow men.

The power of adaptation to varieties in external condition, which renders Man to a great extent independent of them, is one of the most remarkable peculiarities of his economy. He is capable of sustaining the lowest as well as the highest extremes of temperature and of atmospheric pressure. In the former of these particulars he is strikingly contrasted with the anthropoid apes; the Chimpanzee being restricted to the hottest parts of Africa, and the Orang outan to the tropical portions of the Indian Archipelago; and neither of these animals being capable of living in temperate climates without the assistance of artificial heat, even with the aid of which they have not hitherto survived their second dentition. So, again, although Man's diet seems naturally of a mixed character, he can support himself in health and strength either on an exclusively vegetable diet, or, under particular circumstances, on an almost exclusively animal diet. It is in thus adapting himself to the conditions of his existence, in providing himself with food, shelter, weapons of attack and defence, &c., that man's intellectual powers are first called into active operation; and when thus aroused, their development has no assignable limit. The *will*, guided by the intelligence, and acted on by the desires and emotions, takes the place in man of the instinctive propensities which are the usual springs of action in the lower animals; and although, among the most elevated of these, the intelligent will is called into exercise to a certain extent, yet it never acquires among them, the dominance which it possesses in man. The *capacity for intellectual progress* is a remarkable peculiarity of man's psychical nature. The instinctive habits of the lower animals are limited, and peculiar to each species, and have immediate reference to their bodily wants. Where a particular adaptation of means to ends, of actions to circumstances, is made by an individual (as is frequently the case, when some amount of intelligence or rationality exists), the rest do not seem to profit by it; so that, although (as will be shown hereafter) the instincts of particular animals may be modified by the training of man, or by the education of circumstances, so as to show themselves after a few generations under new forms, no elevation in intelligence appears ever to take place spontaneously, no psychical improvement is manifested in the species at large. One of the most important aids in the use and development of the human mind, is the capacity for articulate speech; of which, so far as we know, man is the only animal in possession. There is no doubt that many other species have certain powers of communication between individuals; but these are probably very limited, and of a kind more allied to the "language of signs," than to a proper verbal language. In fact it is obvious that the use of a language composed of a cer-certain number of distinct sounds, combined into words in a multitude of different modes, requires a certain degree of that power of abstraction and generalisation, in which (as elsewhere remarked*) it appears that the lower animals are altogether deficient. The correspondence between the psychical endowments of the Chimpanzee and those of the Human infant before it begins to speak, is extremely close; and those who have perused the interesting narrative given by Dr. Howe, of his successful training of Laura Bridgeman, will remember how marked was the improvement in her mental condition, from the time when she first apprehended the idea that she could give such expression to her thoughts, feelings and desires, as should secure their being comprehended by others.

Now, this capacity for progress is connected with another element in Man's nature, which it is difficult to isolate and define, but which interpenetrates and blends with his whole psychical character. "The soul," it has been remarked, "is that side of our nature which is in relation with the infinite;" and it is the existence of this relation, in whatever way we may describe it, which seems to constitute the most distinctive peculiarity of man. It is in the desire for an improvement in his condition, occasioned by an aspiration after something nobler and purer, that the mainspring of human progress may be said to lie; among the lowest races of mankind, the capacity exists, but the desire seems dormant. When once thoroughly awakened, however, it seems to "grow by what it feeds on;" and the advance once commenced, little external stimulus is needed; for the desire increases at least as fast as the capacity. In the higher grades of mental development, there is a continual looking upwards, not (as in the lower) towards a more elevated human standard, but at once to something beyond and above man and material nature. This seems the chief source of the tendency to believe in some unseen existence; which may take various forms, but seems never entirely absent from any race or nation, although, like other innate tendencies, it may be deficient in individuals. Attempts have been made by some travellers to prove that particular nations are destitute of it; but such assertions have been based only upon a limited acquaintance with their habits of thought, and with their outward observances; for there are probably none who do not possess the idea of some invisible power, external to themselves, whose favour they seek, and whose anger they deprecate, by sacrifice and other ceremonials. It requires a higher mental cultivation than is commonly met with, to conceive of this power as having a spiritual existence; but wherever the idea of spirituality can be defined, it seems connected with it. The vulgar readiness to believe in demons, ghosts, &c. is only an irregular or depraved manifestation of the same tendency. Closely connected with it, is the desire to participate in this spiritual existence, which has been implanted in the mind of man, and which, developed as it is by the mental cultivation that is almost necessary for the formation of the idea, has been regarded by philosophers in all ages as one of the chief natural arguments for the immortality of the soul. By this immortal soul, Man is connected with that higher order of being, in which Intelligence exists, unrestrained in its exercise by the imperfections of that corporeal mechanism through which it here operates; and to this state, — a state of more intimate communion of mind with mind, and of creatures with their Creator, — he is encouraged to aspire, as the reward of his improvement of the talents here committed to his charge.

II. Of *Species* and *Varieties*, zoologically considered.

The meaning which the scientific Naturalist attaches to the term *Species*, is not always defined in the same manner, although the notions which the various definitions are intended to convey, are for the most part essentially similar. Thus a species has been described as "a race of animals or of plants, marked by any peculiar character which has always been constant and undeviating;" it being obvious, from this definition, which carries us backwards from the present to the past, that the first parents or "protoplasts" of such a race must have been distinguished by the same characters as those by which their descendants are now recognised. But, again, this community of parentage is made by Cuvier to constitute the leading idea conveyed by the term; for he defines a species to be "the collection of all the beings descended the one from the other, or from common parents; and of those which bear as close a resemblance to these, as they bear to each other." "We are under the necessity," he elsewhere remarks, "of admitting the existence of certain forms, which have perpetuated themselves from the beginning of the world, without exceeding the limits first prescribed; all the individuals belonging to one of these forms, constitute what is termed a species." And M. De Candolle, in like manner, observes that "we unite, under the designation of a species, all those individuals which mutually bear to each other so close a resemblance, as to allow of our supposing that they may have proceeded originally from a single

* See Art. Instinct, vol. iii. p. 2.

being or a single pair." Thus it appears that, in one mode or another, the fundamental idea of the term, among all those naturalists who admit the "permanence of species," connects itself with the notion of community of descent. This notion, as M. De Candolle admits, is hypothetical, so far at least as its particular applications are concerned; since in no one case have we the power either of looking back to the epoch of the first production of a species, or of tracing downwards the whole line of descent from any original pair. Still, as it is the only definition which conveys the essence of what naturalists ordinarily mean by *species*, we shall accept it as the basis of our further inquiries; and shall now point out the mode, in which it is brought into application in the actual study of natural history.

We will suppose the Zoologist to have two new specimens of shells or insects placed before him, or the Botanist to be examining two new specimens of plants. If the conformity between the two is so extremely close, that the differences do not exceed the limits of variation which are commonly seen to prevail in the offspring of a common parentage, he places them in the same species; because he considers that each may produce a form resembling the other, or may have been produced by it, so that there is no sufficient ground for assigning to the two a distinct ancestry. But supposing that the differences should be more strongly marked, and the naturalist should be tempted to assign different specific names to his two shells, or insects, or plants: in what way is he to diagnose their similarity or diversity of origin? He forms his judgment, in the first place, by the *nature of the characteristic difference;* for this may be of such a kind, that its variability could not be reasonably suspected. Yet this is not a point on which much stress can be laid, when it stands alone; for although in many groups there are certain characters which present such constancy, that a presumption of specific diversity may be fairly entertained if these should exhibit well-marked differences, yet there are too many exceptions to allow such differences to be unhesitatingly admitted as valid specific characters. They may arise, in fact, from three sets of causes; namely, differences in age and degree of development, differences in the conditions under which the individuals have existed, and tendency to spontaneous variation inherent in the race. It is necessary, therefore, to exclude each of these possible sources of error, before the specific diversity of our two objects can be established.

1. It is now universally admitted that the cases are extremely numerous, in which *diversities of age* have led to the establishment of species which have no existence in nature; the forms thus distinguished being those of the same species in different grades of development. The more our knowledge of the history of the lower tribes of animals increases, the more is it found that *metamorphosis* is with them the rule, and not the exception; so that the cases seem comparatively rare, in which an invertebrated animal at its emersion from the egg possesses the characters that serve to distinguish it in its adult condition. And just as the larva, pupa, and imago states of any insect, are all comprehended in a complete account of the species, so must we rank the extraordinary diversities of form presented by the *Medusæ* or the *Balani*, in the early period of their lives, as coming within the limits of *their* specific definitions. It is obvious that this source of fallacy can only be completely avoided, when we have obtained an acquaintance with the *whole history* of the life of any individual, from its commencement to its dissolution, and are thus enabled to say positively what *are*, and what *are not*, alterations producible by age. Where this knowledge cannot be acquired, the only safe basis on which the naturalist can proceed, is that which is derived from a knowledge of these phenomena as presented in the most nearly allied forms; and yet this often fails, as in the case of the *Astacus fluviatilis* (river cray-fish), and *Gecarcinus* (land crab), which undergo no change that can be called a metamorphosis, notwithstanding that in all other Macrourous and Brachyourous Decapods yet observed, a real metamorphosis takes place. Even in the case of extinct species, the history of whose life can never become known to us by any other means than by the preservation of their remains in different stages of growth, the careful comparison of a sufficient series of these remains will sometimes establish a strong probability, if not a positive certainty, as to their mutual relationship: thus, M. Barrande, of Prague, has succeeded in showing that it is next to certain that no fewer than eighteen forms of *Trilobites*, which have been described as distinct species and ranked under ten different genera, are really the successive forms of one and the same species; the differences which they present both in size and conformation being analogous to those that we see in the existing tribes most nearly allied to them, and the whole series constituting one continuous succession. Instances in which new species have been erected among the higher classes of animals, especially among Birds, for the reception of individuals whose differences were only *seasonal*, have been so frequently recorded, that it is sufficient here to mention them. It is obvious that such errors can only be corrected by a knowledge of the seasonal changes which the species is liable to undergo. Of this source of difficulty in the discrimination of species, we need take no account in our future inquiries; for although, in the Orang and Chimpanzee, the alteration in the conformation of the cranium which takes place at the period of second dentition, is so very decided, that it formerly gave rise to much confusion, which has only disappeared before a fuller knowledge of the history of these animals, yet no change of such magnitude occurs in Man; and of the

degree of change which does take place in the several races of mankind, between infancy and old age, there is seldom much difficulty in collecting information.

2. The *influence of external conditions* in modifying the conformation both of Plants and Animals, is a question of fundamental importance in the determination of the value of specific characters. In this respect there is a very extraordinary diversity among the several races of living beings, even among those which are most nearly allied to each other; for whilst some possess such a *capacity for variation*, that they are easily influenced by changes in external conditions, and can, in consequence, readily adapt themselves to these, to others this capacity seems altogether denied. It is from this circumstance that we find particular species, of plants, as well as of animals, restricted to particular conditions in regard to climate, food, &c., their constitutions not being able to adapt themselves to any considerable change; whilst others are more widely dispersed, simply because their constitutions *can* accommodate themselves to alterations in these conditions. Hence a change of food or climate, to which the latter soon become habituated, is fatal to the former. We see this difference well marked in the Feline tribe; for whilst the greater part of the larger species, such as the lion and tiger, are inhabitants of tropical regions, and cannot endure the winter's cold, even in the temperate zone, the domestic cat follows man in almost all his wanderings, and can sustain extremes of heat and cold as well as he can himself. This accommodation is effected by a change in the organism itself, of which evident indications are frequently presented, even within the course of a short time: thus, sheep transported from this country to the West Indies soon loose their covering of thick wool, and acquire in the place of it a short, fine hair, shining and smooth, like that of the goat in his best state, so that after a few years the sheep can scarcely be distinguished from the goats, save by their general conformation; and in this, too, from the usual absence of any considerable accumulation of fat in the bodies of the sheep, there is not nearly so much difference between the two races, as there is in temperate climates.

The continued action of the same circumstances for a few generations, gives increased permanence to the new characters of the breed, so that acquired peculiarities of conformation become *congenital*. Thus, Sir C. Lyell mentions* that some Englishmen engaged in conducting the mining operations of the Real del Monte Company in Mexico, carried out with them some greyhounds of the best breed, to hunt the hares which abound in that country. The great platform, which is the scene of sport, is at an elevation of about 9000 feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about 19 inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps, which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as the fleetest of their race in this country. In fact, it cannot be reasonably questioned, if the history of the domesticated races of animals be fairly considered, that changes in external conditions are capable of exerting a very decided influence upon the physical form, the habits and instincts, and the various functions of life, in species possessing this adaptiveness. The variations thus induced extend to considerable modifications in the external aspect, such as the colour, the texture, and the thickness of the external covering; to the structure of limbs and proportional size of parts; to the relative development of the organs of the senses and of the psychical powers, involving changes in the form of the cranium, and to acquired propensities, which, within certain limits (depending, it would appear, on their connexion with the natural habits of the species) may become hereditary. Of the changes in *psychical* characters thus induced by external circumstances, the following are trustworthy examples. We are informed by M. Roulin (to whose researches on the changes which the domesticated races, introduced by the Spaniards into South America, have subsequently undergone, we shall frequently have occasion to refer), that a race of dogs employed for hunting deer in the platform of Santa Fé, in Mexico, is distinguished by the peculiar mode in which they attack their game. This consists in seizing the animal by the belly, and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs; the weight of the animal thus thrown over, being often six times that of its antagonist. Now, the dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running; and even should the deer, not perceiving him, come directly upon him, the dog steps aside, and makes his assault upon the flank. On the other hand, European dogs, though of superior strength and general sagacity, are destitute of this instinct; and for want of similar precautions, they are often killed by the deer on the spot, the cervical vertebræ being dislocated by the violence of the shock.* A new instinct has also become hereditary in a mongrel race of dogs, employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped peccari. The address of these dogs consists in restraining their ardour and attaching themselves to no individual in particular, but keeping the whole in check. Now, among these dogs, some are found, which, the very

* Principles of Geology, seventh edit. p. 568.

* Annales des Sciences Naturelles, 1829, tom. xvi. p. 16.

first time they are taken to the woods, are acquainted with this mode of attack; whereas a dog of another breed starts forward at once, is surrounded by the peccari, and, whatever may be his strength, is destroyed in a moment. The fixed and deliberate stand of the pointer, again, whether taught by the agency of man, or a habit engendered, like the preceding, by the force of circumstances, is so intimately connected with the constitution of the race, that occasionally it becomes hereditary; a young pointer, taken into the field for the first time, being often observed to perform its duty as well as its long-trained seniors. A still more remarkable example of the transmission of acquired psychical peculiarities, is afforded by the case of the retriever, a breed of dogs which has been trained to keep close to the sportsman until he has fired, and then to go in search of the game which he has wounded or brought down. It is obvious that this habit could only have been taught by the agency of man; and yet it has been frequently observed that a young retriever, on the very first occasion of being taken into the field, has conducted itself as well, and brought back game with as much steadiness, as older dogs which had been schooled into the same manœuvre by means of the whip and collar.*

No really philosophical botanist or zoologist, then, should venture to establish specific distinctions between two races, otherwise than *provisionally*, until he has been able to assure himself that the one may not be converted into the other by a change in external conditions. Characters which are of the most trivial kind in themselves, may be valid grounds of specific distinction, if they are *not* liable to be thus affected; on the other hand, characters which would be accepted in one group as sufficient for the separation of genera, may be found totally inadequate in another for the discrimination of species, being liable to modification under a very slight change of external conditions. Every one is familiar with the changes which have been induced in plants by cultivation, — how a "single" flower is converted into a "double" one; how the spines, prickles, and thorns covering the surface may be obliterated (a change which was fancifully, but not improperly, termed by Linnæus "the taming of wild fruits"); and how the wavy leaves may become thick and fleshy (as in the change of the *Brassica oleracea* into the cabbage), or the slender flower-stalks may be converted into a substantial mass (as in the conversion of the same plant into the cauliflower). These changes do not, as some have alleged, throw the least doubt on the "permanence of species," or favour the doctrine of "transmutation" in the slightest degree; for however wide may be limits of variation, each species *has* its limits; and so far from having permanently advanced, under the influence of cultivation, to a superior type of structure, the plants thus modified will all return to their original form, when subjected to their original conditions. Numerous instances might be cited from the British Flora alone, in which the most experienced botanists are in disagreement upon the question of specific unity or diversity, simply because they have not yet ascertained the limits to the variations which the same plant may present, when growing under a variety of external conditions; and the difficulty is yet greater when British and Continental species are compared, the variety of external conditions being greater, and the amount of allowance which should be made for their influence being known in but a few cases. The same may be said of Animals; particularly of those on which the influence of domestication has been brought to bear. Upon this point, however, we shall defer enlarging, until the next head of the inquiry has been considered.

3. A *tendency to variation* exists in many races, which manifests itself rather in modifications of the specific type presented in the course of successive generations, than in the alterations induced by external agencies in the individuals of one generation. Thus we find that the offspring of any one pair do not all precisely agree among themselves, or with their parents, in bodily conformation or in psychical character; but that *individual* differences (as they are termed) exist among them. Now, as this tendency to variation cannot be clearly traced to any influence of external circumstances, it is commonly distinguished by the term 'spontaneous;' but there is much to favour the belief, that such variations are attributable to agencies operating either on both parents, previous to their intercourse, or at the time of coition, or to influences acting on the female during the period of utero-gestation.* For it may be uniformly observed, that those animals exhibit the greatest tendency to this 'spontaneous' variation, which present the greatest constitutional adaptiveness to a variety of external conditions. And there are many cases in which it seems pretty clear, that the cause of this variation must be looked for in that combination of influences, which is known under the general term *domestication*. Thus it may be stated as a general fact, that the varieties of colour so remarkable in domesticated races, tend to disappear when these races return in any considerable degree towards their primitive wild state. This has been especially noticed in the horses, cattle, sheep, hogs, and dogs, introduced by the Spaniards into South America; and the observation has been confirmed in other parts of the globe, showing that there is nothing peculiar to the climate of that country, which brings about the altera-

* See Mr. P. A. Knight's Paper on the Hereditary and Acquired Instincts of Animals, in the Philosophical Transactions for 1837.

* As these modifications are witnessed in domesticated birds no less than in mammals, it is obvious that the latter source of influence is excluded in their case; and we must fall back upon the probability of a change in the constitution of the parents, previously to the generative act.

tion. Now this has been attributed to the free intermixture of differently-coloured parents, which tends to confuse the breeds, and to merge those varieties which are artificially kept up among domesticated races by the matching of similar parents. But although this cause doubtless operates, yet it is far from being the whole truth; for the converse occurrence may take place in animals which are in process of being reclaimed from their wild state, under circumstances that forbid the idea of any such intermixture. Thus, Mr. Bell informs us that an Australian bitch, or *dingo*, had a litter of puppies, the father of which was also of that breed; both parents had been taken in the wild state; both were of the uniform reddish-brown colour which belongs to the race; and the mother had never bred before; but the young, bred in confinement, and in a half-domesticated state, were all more or less spotted.* Now, considering the strong evidence which exists, that the colour of the offspring, in animals in which the hue is disposed to vary, may be affected by a mental impression at the time of impregnation†, it does not seem improbable that various differences in the general condition of a wild and of a domesticated animal, should so affect the constitution of the latter, as to occasion an amount of variation in its offspring which does not exist in the former. — The same general rule holds good in Plants. The tendency to the (so called) spontaneous production of varieties, is the greatest in those species which are most susceptible of influence by cultivation; and those which are themselves least changed by external conditions, are those which are observed to transmit their distinctive characters most constantly and uninterruptedly from one generation to another. Further, the influence of cultivation will sometimes develop in the individual the very same departures from the usual specific type, which are, in other cases, 'spontaneously' manifested in the offspring of a common parent. Thus, it is well known that, by cultivation, the primrose may be converted into the polyanthus, and the cowslip into the oxslip; but the late Dean of Manchester raised all these four forms from the seeds of the same plant; and Professor Henslow has been equally successful.

Until the limits of this tendency to spontaneous variation have been determined, therefore, in each particular instance, no valid specific distinctions can be erected. It happens, in certain groups, that a peculiarity, in itself very trivial, is transmitted uninterruptedly from one generation to another, with such constancy and regularity as to justify us in believing that it has been always manifested. Thus many of the reputed specific differences of Moths and Butterflies rest on no other foundation, than the constant presence of a certain spot on some part of their wings; and there are Felines, which agree so closely in the structure of their skeletons as not to be distinguishable osteologically, and which are only regarded as belonging to distinct species, because a certain stripe or spot, which uniformly shows itself on the skin of one, is as uniformly absent from that of the other. On the other hand, we see, in all our domesticated races, great diversities among the offspring of a common parentage; and these differences are sometimes so marked, that if he had not positive evidence of this common parentage, the naturalist would undoubtedly be justified, by the importance of the diversity, in the establishment of numerous specific types, when he has really seen but a few of the varieties into which one and the same may pass.

Of this tendency to "spontaneous" variation, it may be remarked, further, that like the variation which may be traced to external conditions, it has its limits, and does not really tend to confuse the boundaries of species, although it may frequently show the necessity for their extension. Thus, notwithstanding the multitude of varieties of the Apple and the Pear which we possess, and notwithstanding the apparent triviality of the specific distinction between them (this being little else than the existence of a gritty centre in the pear, which is absent in the apple), yet we never find this distinction confounded by the presence of the distinctive characters of the pear in the descendant of an apple, or by the absence of it in the descendant of a pear. So we find that, notwithstanding the multiplication of breeds of dogs and horses, sheep and oxen, pigs and poultry, they all retain the characters by which their respective kinds are distinguished from their congeners. There is no tendency to an obliteration of the distinctions between a dog and a fox, or between a horse and an ass; but these distinctions are perpetuated with the same regularity, that marks the stripes of the leopard or the spots on the wing of a moth. But, on the other hand, by observation of the spontaneous changes which particular tribes of plants or animals are liable to exhibit, we are sometimes led to extend our ideas of the comprehensiveness of species, and to bring into the same category forms which were previously supposed to be distinct types. Thus, for example, it is the opinion of many distinguished naturalists, that not only are all the breeds of Dogs to be considered as constituting one species, but that this species must also include the Wolf; or, in other words, that the wolf and the dog are to be considered as collateral descendants from the same original parents. We shall presently examine more in detail the evidence on which this belief is founded; supposing it to be correct, we are only required to enlarge our idea of the comprehensiveness of the species *Canis lupus*, which must then include all the breeds of *C. familiaris* as its varieties; and none of them are in any more danger than before, of being confounded with the fox or the jackal. Until, however, the limits of

* British Quadrupeds, 2d edit. p. 203.

† See a valuable collection of such cases by Dr. Harvey, in the Edinburgh Monthly Journal for November, 1850.

variation have been clearly determined in the case of any species which is known to exhibit the tendency, it is obviously impossible to erect specific distinctions that shall possess anything but a provisional value ; and thus the naturalist may feel a confident assurance of the genuineness of one set of species in a natural group, whilst he is utterly at a loss respecting another.

Reverting, then, to the "idea" of a *species,* as involving descent from a *common,* or at any rate from a *similar* parentage, in all the individuals composing it, we have to aim at ascertaining, in the case of two or more beings whose specific identity or distinctness is a question for our determination, whether their characters are presented so fixedly and determinately in all the individuals of the same and of successive generations, as to justify us in believing that they *have been* thus preserved through all time, and under all changes of external conditions. According to the amount and correctness of our information upon this question, will be the validity of our specific distinctions; on the other hand, according to the hastiness and crudity of our decision, will be its liability to be overthrown by subsequent researches. Of course, where the progeny of any known stock can be traced through a long period of time, and under great varieties of external conditions, and their successive variations have been noted, this evidence must outweigh every argument founded upon the supposed importance of the characters which are found to undergo modification. But such opportunities are too frequently wanting; and the naturalist is obliged to have recourse to means of discrimination which are less certain, but which will frequently conduct him, provided that his researches have been sufficiently extensive, to a satisfactory conclusion. The great point at which he should aim, is the assemblage of as many forms as possible of each type ; and having done so, he will carefully compare them with each other, for the sake of determining whether the supposed specific characters are constant and well-marked throughout, or whether they tend to run together by intermediate gradations. If the first of these should prove to be the case, great confidence may be entertained of their genuineness; but if the second, we may feel an almost certain assurance of their invalidity. Thus, to revert to the case of the apple and the pear, the persistence of their distinctive characters through all the numerous varieties of each, renders it almost certain, that in all other varieties which may hereafter present themselves, the same constancy *will* obtain; and that it *has* obtained during the entire succession of generations of pears and apples, from the time of their first propagation. But let us take an opposite case. Two *Terebratulæ* are brought together from different parts of the great Southern Ocean, the one of which has the edges of the valves of the shell thrown into deep plications, whilst in the other they are quite smooth. Now in most other Bivalve Mollusca, such a difference would be justly admitted to afford a valid specific character; and the conchologist who had only these two shells before him, would be justified, by the usual rules of the science, in ranking each as a distinct specific type. But as his collection extends, intermediate forms come into his possession; and at last he finds that he can make a continuous series, passing, by the most gradual transition, from the smoothest to the most deeply plicated form. Thus, then, the supposed validity of this distinction is altogether destroyed ; and it becomes evident that the most plicated and the smoothest of these *Terebratulæ* must be regarded as belonging to one and the same species, notwithstanding the marked diversity of their extreme forms.

Hence, whilst new types are continually being discovered, the progress of research is tending to diminish the number of species previously enumerated; for there are many groups in which an immense reduction has been effected, by bringing together all those which are found to be nothing else than successive stages of the same individual, and by ranking under one designation all those which are either known or strongly suspected to be mere varieties, resulting from the direct influence of external conditions upon themselves or upon their ancestors, or produced through the obscurer operation of these influences on the act of generation. Frequently it is found that forms which have even been accounted *generically* distinct, are in reality specifically identical. Thus it has been shown by Professor Henslow, that the "rust of corn" (*Uredo rubigo*) is but an earlier form of the "mildew" (*Puccinia graminis*); the one form being capable of development into the other; and the fructification characteristic of the two supposed genera having been produced from the same individual. And it is asserted by Fries, that out of a single species of *Thelephora,* more than eight genera of Fungi have been constructed by various authors. So among higher plants, the invalidity of the generic distinctions on which reliance is usually placed, has been shown, so far as the *Orchideous* tribe is concerned, by the fact that the *same individual* has borne the flowers and pseudo-bulbs usually accounted characteristic of *three* distinct genera, and that another individual has presented the character of a fourth.* So in the animal kingdom, it has been shown by Professor Milne Edwards, that the polypidom of *Tubulipora verrucosa,* according to the circumstances under which it grows, may present the characters of three other reputed genera. If it be attached to a plane surface, as the expanded lamina of a sea-weed, it remains circular, and

* For the first of these cases, see the Linnæan Transactions, vol. xvii. The second fell under the writer's own observation in the Durham Down Nursery, near Bristol; here, also, three different forms, generally considered as generically distinct were presented ; and two of them were the same as in the preceding case : but the third was one not exhibited by that plant.

increases with great regularity, constituting the *Madrepora verrucosa* of Fabricius. If it cluster round the cylindrical and branching stem of a Fucus, it increases irregularly, and assumes the form of the *Millepora tubulosa* of Ellis. If its development in any direction be checked by a mechanical obstacle, the form of the mass will again be changed, and its tubes will be recurved backwards; a character on which Lamouroux founded his genus *Obelia*. Sometimes on the very same polypidom, we find one portion whose disposition corresponds with that of *Millepora tubulosa*, and another which, if detached, would be considered a specimen of *Obelia tubulifera*.* Many similar cases might be quoted; all of them showing, not that there is any real confusion amongst species and genera, but that naturalists have too often assumed variable and non-essential characters as the basis of their systematic distinctions, in ignorance of those which are fixed and determinate. Thus, in the case in question, it is on the structure of the *animal*, not on the form of the *polypidom*, that the modern Zoophytologist places his chief reliance; and a knowledge of this would have prevented the assignment of the varieties of coral, formed by one and the same kind of animal, to three different genera. So among Mollusca, it has been shown by Mr. Gray † that a large number of species have been formed, in consequence of the variations presented by the shells of the same species at different periods of life, or developed under different circumstances. The change from salt or fresh water to brackish, or from brackish to salt or fresh, which many species are able to sustain, appears to have a considerable influence on the form of their shells; thus Professor E. Forbes has shown that certain *Paludinæ* and *Naticæ*, which are found in successive tertiary strata in the island of Cos, associated in some cases with decidedly fresh-water, and in others with decidedly marine, testacea, are probably to be regarded as varieties of the same species, notwithstanding that they would be regarded by conchologists as distinct; gradations being traceable between one form and another, and the changes being of a kind which are known to take place among fresh-water mollusca. ‡

As an example of the mode in which the philosophic zoologist proceeds in his examination of a doubtful case of unity or diversity of species, in a group more closely related to man, we shall consider the question of the relations of the several races of Dogs to each other. Every one is familiar with the fact that numerous breeds of dogs exist in almost every part of the world inhabited by civilised man, distinguished from each other by well-marked peculiarities, which appear to be transmitted continuously from parent to offspring, and thus to possess a claim to rank as specific distinctions. These differences extend to stature, form, proportions, swiftness of foot, colour and texture of hair, acuteness of sensations, intelligence, and attachment to man; and they are particularly well marked in the conformation of the cranium, the part to which the anatomist first looks for his distinctive characters.

The changes in the conformation of the cranial portion of the skull, which distinguish the domesticated races of the dog from those which have been less modified by the influence of man, partly consist in the obliteration of the sagittal crest, which rises up on the line of junction of the parietal bones, and of its continuation on the occipital bone. In the large deer-hound, we are assured by Prof. Owen, these cristæ are as strongly developed as in the wolf; whilst in the smaller spaniel or pug, they are entirely wanting, the cranial dome being smooth and round. But "such modifications," as Prof. Owen remarks, "are unaccompanied by any change in the connections, that is in the disposition of the sutures, of the cranial bones; they are chiefly due to arrests of development, — to retention of more or less of the character of immaturity; even the large proportional size of the brain in the smaller varieties of house-dog, is in a great degree due to the rapid acquisition by the cerebral organ of its specific size, agreeably with the general law of its development, but which is attended in the varieties cited by an arrest of the general growth of its body, as well as of the particular developments of the skull in relation to the muscles of the jaws." Such an alteration is considered by this eminent anatomist as fairly referable to the influence of domestication; since, as he remarks, "no other domestic animal manifests so great a range of variety in regard to general size, to the colour and character of the hair, and to the form of the head, as it is affected by different proportions of cranium and face, and by the intermuscular crests superadded to the cranial parietes." "Yet under the extremest mask of variety so superinduced," he continues, "the naturalist detects in the dental formula, and in the construction of the cranium, the unmistakable generic and specific characters of the *Canis familiaris*." * Generally speaking, the cranial cavity of the domesticated dogs is relatively increased in capacity; the facial portion, on the other hand, is oftener shortened. The skull of the Australian *dingo* differs but little from that of a wolf. In both, the arch formed by the temporal and parietal bones is much depressed, so that the cranial cavity is small, and the head flat. The Danish dog and the mastiff resemble the dingo in the shape of their heads, and display as little of intellect or sagacity. The terrier and the hound have the parietal bones more arched, and, consequently, possess a larger cranial cavity. The greyhound has a longer muzzle, and smaller frontal sinuses than the hound;

* Mémoire sur les Tubulipores, in Ann. des Sci. Nat., 2ème série, Zool. tom. viii.

† On the Structure of the Shells of Mollusca, Philosophical Transactions, 1833.

‡ Travels in Lycia, vol. ii. p. 199.

* Zoological Transactions, vol. iii. p. 415.

and the nasal cavity, though elongated, is much contracted, especially at its upper part, so that the sense of smell is less acute in this breed than in most others. The shepherd's dog, which Buffon very erroneously considered as the breed least modified by domestication, is distinguished by its remarkably capacious cranium; the temporal bones not beginning to arch over the cavity, until they have risen perpendicularly to half their height. In the spaniel and Newfoundland dog, the capacity of the cranium is yet greater than in the preceding; and they are also distinguished by the remarkable size of their frontal sinuses, which causes the forehead to rise almost perpendicularly from the nasal bones. The bull-dog, on the other hand, is distinguished by the shortness and extraordinary breadth of its muzzle; while its cranium is less capacious than that of the shepherd's dog. The varieties in general conformation are not less remarkable than those in cranial configuration. Thus, the relative length of the tail is subject to great variation, even the number of its vertebræ differing so widely as from 16 to 21. Some races have an additional claw on the hind foot; and many have an additional false molar on one or both sides. The nature of the hairy covering, too, varies in regard to its closeness or scantiness, its length, its colour, the fineness or coarseness of its texture, &c. &c.; so that, as M. Fred. Cuvier remarks, the dog-kind presents all the varieties, in respect to the nature of the hairy covering of the body, that are to be found in the entire class of Mammalia. The form of the ears, too, is another marked feature of distinction; these organs being short and erect in some, long and pendulous in others. The differences in habit and psychical character, also, are almost as characteristic as those of form. The greater number of dogs track their prey by scent; and this quality may be developed by care in breeding*, so that it attains its greatest excellence in the highest-bred fox-hounds, blood-hounds, and pointers. But the greyhound hunts almost solely by sight; and, in breeding it, every care is taken to obtain swiftness and "wind," and power of enduring sudden and violent bursts of exertion. In the degree and nature of their attachment to man, again, which is the most marked psychical feature common to them all, we observe a very striking diversity. Perhaps the bull-dog is, of all the domesticated races, that which is least prone to seek the society of man; yet, notwithstanding its obstinacy and ferocity, it does form attachments to human beings, and especially to those whose savage nature is most akin to its own. On the other hand, the pug, which seems like a dwarf-variety of the bull-dog, is remarkably timid; and, though possessing but little sagacity, is tolerably good tempered. The mastiff, again, possesses the determined courage of the bull-dog, but is greatly influenced by kindness, and shows a generous and intelligent nature. The setter, with a considerable degree of sagacity and intelligence, is remarkable for its affectionate and grateful nature, for its docility, and for its humble and anxious solicitude to please. Of all the races of dogs, the spaniel is the one most distinguished for attachment to man; the most timid, fond, and affectionate; the most patient under ill treatment: it is, however, by no means distinguished for courage; and though very docile, is not remarkable for native sagacity. It is perhaps in the shepherd's dog that the attribute of intelligence is most strikingly displayed, in combination with courage, fidelity, and perseverance: he lives in habits of constant familiarity with his master, learns to interpret his looks and words with an intuitive comprehension, and allows no difficulty or danger to prevent him from carrying his directions into effect. The Newfoundland dog, perhaps, combines more than any other breed the qualities which render the race most generally serviceable to man; although this combination is not such as fits him for any of those special uses, to which other breeds are particularly adapted.

Now these differences are far greater than those which exist among the acknowledged *species* of the feline race*; and therefore, at first sight, might be considered as amply justifying the erection of specific distinctions among the several breeds of the canine. But the endeavour to do so would be attended with insuperable difficulties; for, in the first place, it has been shown by M. Fred. Cuvier†, who has paid particular attention to this question, that if we assume the varieties to be permanent races, or originally distinct species, and predetermine that these races are susceptible of few or no modifications, it will be requisite to institute *at least fifty different species* of dogs, all distinguished from each other by recognisable characters, — a hypothesis which cannot for a moment be entertained. Moreover, every one who has much intercourse with the canine races becomes impressed with the feeling, that, notwithstanding the diversities of the greyhound and the bull-dog, the blood-hound and the spaniel, the Newfoundland and the terrier, they are all *dogs;* and there is obviously an instinctive recognition of this fact among the animals themselves, as is seen by the readiness in which the individuals of the most dissimilar breeds will fraternise together. Further, as already remarked, there is a marked absence of tendency to variation in the characters of the feline races, the limits of each

* The principal mode in which the influence of man is exerted in modifying the characters of the races under his control, consists in the selection of those individuals only for propagation, which display the desired attributes in the greatest perfection.

* The writer has been assured by Mr. S. Stutchbury, who was formerly sub-curator of the museum of the Royal College of Surgeons, that even Cuvier proved himself unable to distinguish the cranium of a lion from that of a tiger.

† Recherches sur les Caractères Ostéologiques, qui distinguent les principales Races du Chien domestique. Annales du Muséum, tom. xviii.

species being defined by the preservation of its characters through successive generations and under all circumstances; the only exception to this general statement, being in the case of the domestic cat, which, like the dog, passes into numerous varieties, none of which, however, show an approximation to the characters of any other species. Hence, notwithstanding the extent of variation presented among dogs, the characters of the breeds do not bear a specific value; for an amount of variation may be seen among the successive generations of the same breed, however pure it may be kept, or even among the offspring of the same litter, quite sufficient to show that a strong capacity for modification exists in this species. It would not be difficult, moreover, to bring together a series of individuals, that should connect the most extreme forms by imperceptible gradations; all the different races breed together with the most complete freedom; and, as already remarked, there is a continual tendency amongst them, if they escape from the influence of man, and intermingle unrestrainedly in a state approaching to their original wildness, to a return to one uniform type of configuration and of hue. Further, whatever their other differences in psychical character, we find that they all agree in that tendency to association with man, which is pretty obviously the chief source of those diversities; the most important departures from the natural habits of a wild race, being those which have been impressed upon the several breeds by a long course of training, whose influence has been transmitted, to a certain extent, from one generation to another. We have seen that, in particular races of dogs existing in a half wild state, the force of circumstances, without any human intervention, has developed a new instinct, which has become hereditary within a few generations; and there can be no difficulty in understanding, therefore, that the psychical as well as the physical characters of the dog may have undergone a far more marked alteration, in the prolonged period during which he has been under the influence of man. However considerable, then, are the *anatomical* and *psychological* differences of the most diverse breeds, these are perpetuated only by the agency of man, and tend to merge themselves in a common type as soon as this is withdrawn; and through all these changes, the *physiological* conformity, as marked especially by the generative function, is constantly preserved. And thus it may be unhesitatingly asserted, that there is no such clear and well-marked *natural* distinction between the several breeds of dogs, as can serve to justify the assignment of a separate parentage to any of them.

The question next arises, whether the dog is a domesticated form of any other species of the genus *Canis*, *e. g.* the wolf, the fox, or the jackal; or whether it is descended from an original wild stock, which has subsequently become extinct. Now the fox may be at once excluded, as differing in the vertical elongation of the pupil, the peculiar bushiness of the tail, and in other characters. The affinity of the dog to the jackal is certainly not so close as that which it bears to the wolf; and there are many distinguished naturalists who regard the latter as its original. In support of this view, the following considerations may be urged. No specific character has yet been framed so as to be equally applicable to all the breeds of dogs, which does not include the wolf also; and it does not seem likely that any valid specific distinction can be established upon anatomical grounds only. The various races of wild dogs, in proportion to their entire emancipation from the influence of man, exhibit more and more of the lank and gaunt form, the lengthened limbs, the long and slender muzzle, and the great comparative strength, which characterise the wolf; and in the dingo of Australia, which presents these peculiarities in the most marked degree, and which may be considered as the most remote from a state of domestication, the tail assumes the slightly bushy form of that of the wolf. In no point of its osteology does the wolf differ more from dogs in general, than they differ from each other; and the interval, in fact, is much less between the wolf and the races of dogs just alluded to, than it is between these and the races which most strongly exhibit the influence of domestication. Further, the wolf and the dog readily breed together, and their progeny is fertile with either of the parent races; but whether the hybrids thus produced are fertile with each other, and a new race can be thus established, has not yet been ascertained. The term of utero-gestation is the same for the wolf as for the dog, viz. sixty-three days; that of the jackal, on the other hand, is but fifty-nine. It is a remarkable fact, that the habit of *barking* is peculiar to dogs which have been accustomed to intimate association with Man; and, like variety of colour, it is soon induced in the progeny of those to whom it is not natural, when these are reared in a state of domestication. Thus, the puppies of the Esquimaux dogs brought home by our Arctic explorers, being accustomed to the sound of the human voice from the earliest period, learn to bark, whilst their parents remain confined to their original sounds.

The principal objection to the idea of the specific identity of the two races, lies in their difference of psychical character; the wolf being apparently altogether destitute of that disposition to attach itself to man, and of that capacity of modification under his influence, which is so marked a feature in the nature of the dog. It has been asserted that the wolf is so untameably savage, that it would require ages of domestication to render it even moderately tractable, if, indeed it could ever be brought under subjection. Such an assertion, however, does not seem borne out by facts. Mr. T. Bell* relates an

* British Quadrupeds, p. 199.

instance of friendly recognition towards himself and other persons, shown by a bitch wolf at the Zoological Gardens ; and cites from Mr. Fred. Cuvier a very remarkable instance of affectionate and submissive attachment shown by a young wolf towards the individual by whom he had been brought up, in a degree that scarcely seems inferior to that manifested by the dog. "Now, if we find," he remarks, "that the mere education of a young wolf, taken from its parents in a wild state, could so far change its natural disposition, and render it so fond, so intelligent, and so grateful as this, what may we not expect from the successive transmission of improvement by the culture and training of a whole race for ages?" On the other hand, in those races of dogs which have become emancipated from human control, the *psychical* nature of the wolf developes itself, in precise proportion to the approach presented to its *physical* characters. And even in the most domesticated breeds, instances of spontaneous reversion to wild habits are occasionally to be met with. "Thus," says Mr. Blyth, "I have known this to occur in a male pointer and a female greyhound; the latter was so fine a specimen of the breed, that on being entrapped, it was thought desirable to obtain a litter from her, which was accordingly effected ; but while her puppies were very young, she managed to escape to the woods, and never returned ; three of her progeny grew to be excellent hounds, but *two others proved quite irreclaimable*, and escaping from servitude, like their dam, were finally shot, for their destructive poaching propensities."*

Thus it appears that, even if we hesitate in pronouncing in favour of the specific identity of the dog and the wolf, there is, at any rate, no valid ground for the establishment of a specific distinction between them ; and if it should prove that the hybrid offspring are fertile amongst themselves, and that a vigorous mixed race is the result, the probability of their specific identity would be greatly increased. The required *proof*, however, could only be afforded by the actual production from the wolf stock, of a race having the aptitude for domestication, and capacity for variation, exhibited by the dog.

There is another mode of looking at the question, however, which has been recently suggested by Professor Agassiz.† This distinguished naturalist thinks it impossible to account for the geographical distribution and varieties of conformation of many existing species of animals, without having recourse to the idea that, instead of all the individuals of that species having descended from a single parentage, or pair of 'protoplasts,' they are the offspring of several distinct pairs of 'protoplasts,' first introduced in different localities, all possessing the same essential nature, but having that nature modified in accordance with the special conditions in which each was destined to exist. From the definition of species, therefore, he would exclude the idea of *identity* of descent, and would substitute that of *similarity*; but would still base his distinction of species, as do other naturalists, on the constant transmission of some well-marked peculiarity common to all the races, and would thus associate all those which obviously partake of a common nature, and are disposed to free intermixture, notwithstanding the non-identity of their parentage.* He would probably accord with other naturalists, therefore, in regarding the different breeds of dogs as varieties of one species ; but would attribute the origin of their several peculiarities *in part* to the differences in their first parents, which were not, however, sufficient to constitute specific distinctions. Although there may be cases in which such an hypothesis presents the readiest solution of the difficulty, yet it can scarcely be accepted as applicable to that of the dog ; for we do not here find that the races which most nearly approximate to the wild state in different parts of the world, do present any differences that enable us to regard them as the respective ancestors of our most diverse domesticated breeds. If, for example, it could be shown that the Esquimaux dog peculiarly resembled the mastiff, that the Indian *dhole* might be regarded as the progenitor of the greyhound, that the

* Translation of Cuvier's Règne Animal, p. 90.

† See his recent work on the Fishes of Lake Superior ; also the Edinb. New Philos. Journ., April, 1850.

* Of the hypothesis of the radiation of species from several distinct centres, Prof. E. Forbes may be regarded as the most conspicuous opponent. He has laboured to show that the peculiarities in the geographical distribution of existing species are quite reconcilable with the idea of migration from single centres, and that, generally speaking, they necessarily lead to that idea; whilst, on the other hand, in those instances in which detached or outlying spots occur, remote from the principal area of distribution, and from each other, he considers that these represent the original extent of range, which has been subsequently interrupted by geological changes that have been fatal to the existence of the species over the intermediate connecting areas,—as, by the substitution of water for land, or of land for water; by the elevation or depression of the sea-bottom, in a degree incompatible with the continued existence of the species if it be marine ; by similar changes in the land, exerting a like influence on terrestrial species; by alterations thus induced in the course and connection of rivers and watercourses, which have broken up the areas of fluviatile and lacustrine species; by changes of temperature consequent upon remoter causes; and many other influences too numerous here to recount. He affirms that, in so many cases, these peculiarities may be thus explained by *known* geological changes, which have occurred since the introduction of the species in question (this being the case peculiarly with those that existed in the *glacial* epoch, and then had an extensive southern range, which is now only indicated by their occurrence in outlying spots, the principal area of the species being now restricted to the circum-polar regions, in consequence of the more elevated temperature of the parts beyond), that we have fair ground for extending this view to all, and for *inferring* the occurrence of geological changes, subsequently to the first diffusion of particular species, from the peculiarities of its existing distribution. As yet, however, his views on this subject have not been given to the world in any complete form, save by oral discourses.

Australian *dingo* was the probable ancestor of the spaniel, and that the American wild-dog gives us the type of the pug, the hypothesis of Professor Agassiz might be admitted to possess a considerable claim to our reception. But so far is this from being the case, that, as already pointed out, the several races of wild dogs present a remarkable conformity to a common type; and neither of them can be looked to, in preference to the others, as the probable source of those domesticated breeds which are most diverse from each other, and from the supposed common type. Moreover, there is a strong probability, considering the very remarkable character of the zoology of New Holland, that the *dingo* was not indigenous to that country, but that it was introduced there by its human colonizers; thus, being a descendant of the Indian *dhole*, or of the same stock with it. Hence, even if we admit the multiplication of 'protoplasts' in the case of the dog, we are still driven back upon the influences of domestication as the direct or indirect source of those variations from the fundamental type, by which the existing races are severally characterised.

The historical evidence of modification in successive generations, which is inadequate to prove the specific identity of the several races of Dogs, is much more fully supplied in the case of some other domesticated animals; and suffices to show that although the tendency to spontaneous variation may seem to have nearly exhausted itself heretofore in the production of the most divergent forms, still there remains enough to originate new races, distinguished by well-marked peculiarities of conformation, even under our own eyes. Some of our most valuable information on this subject, is derived from the changes which have taken place in the races of domesticated animals introduced into the West Indies and South America, by the Spaniards, three centuries and a half since. Many of these races have multiplied extremely in a soil and in a climate congenial to their nature; and several of them have run wild in the vast forests of America, and have lost all the most obvious appearances of domestication, whilst they have acquired various peculiarities which distinguish them from their domesticated progenitors, some of these, perhaps, being indications of a partial restoration to the primitive characteristics of their respective races. The greatest part of our knowledge on this subject is derived from the researches of M. Roulin (already referred to) which relate to New Grenada and Venezuela, and from the well-known and justly esteemed work of D'Azara on the natural history of Paraguay.

No zoologist has any doubt whatever, that the *wild boar* is the original of our domesticated *swine;* the change from the one form and condition to the other being capable of accomplishment in the course of a few generations. Yet, as Blumenbach has remarked, the difference between the two forms of crania is as great as that between the Negro and the European skulls. And the same eminent physiologist has pointed out, that the varieties of swine in various countries, all clearly referable to one stock, exceed in their extent of divergence from it, the very widest departures of the human conformation from any one type. Thus, swine with solid hoofs were known to the ancients; and large breeds of them are found in Hungary and Sweden, as also in some parts of England. In some other breeds there are five distinct toes, each having its own hoof. The European swine, first carried by the Spaniards to the island of Cubagua, in 1509, have been the progenitors of a race now found there, possessing toes of half a span in length. The hogs which were first introduced into South America by the Spaniards at about the same period, rapidly extended themselves over the northern and central parts of that continent; and whilst wandering at large in the vast forests of the New World, and feeding on their original diet of fruits and seeds, they have reverted very nearly to the type of the European boar. Their colour, too, has lost the variety observable in the domestic breeds, the wild hogs of the American forests being for the most part uniformly black. The hogs which cover the mountains of the Paramos, where they are subject to severe cold and deficient nourishment, are small and of a stunted figure; but their skins are covered with thick fur, often somewhat crisp, beneath which is found in some individuals a species of wool. In some of the warmest regions, the swine are not uniformly black, but red like the young peccari; and elsewhere there are some, whose blackness gives place under the belly to a white band, which reaches up to the back.

The question of the original source of the various breeds of *ox*, will not be now discussed; it is sufficient for our present purpose to notice some of the most remarkable departures from the European type, which have shown themselves in the South American descendants of the individuals first introduced there by the Spaniards. In the year 1770, as we learn from D'Azara, a hornless bull was produced in Paraguay, which has been the progenitor of a race of hornless cattle that has since multiplied extensively in that country. So, again, as we are informed by M. Roulin, in some of the hot provinces of South America, a variety of ox has been produced, which is noted for its extremely rare and fine fur. This variety tends to perpetuate itself; but it is not encouraged, because the "pelones" (as they are termed) are too delicate in constitution to bear the cold of the Cordilleras, to which the cattle are driven for the provision of the towns situated upon them. These pelones obviously constitute a variety adapted for a particular climate; oxen of other breeds frequently perishing when driven into the provinces inhabited by them, or being with difficulty acclimatised.* But the same hot provinces

* Hence we see that so much of Prof. Agassiz' argument for the multiplicity of specific centres, as

occasionally produce another curious variety, characterised by the entire absence of hair; these naked-skinned oxen, which are called "calongos," are, like the pelones, unable to bear a cold climate, and are very delicate and weak. Another remarkable fact, relative to the oxen of South America, is recorded by M. Roulin. In Columbia, the practice of milking cows was laid aside, owing to the great extent of the farms and other circumstances. In a few generations, the natural structure of the parts and the natural state of the function have been restored; the secretion of milk taking place only so long as the calf remains with the mother, and ceasing if it dies or is removed. Hence we have a valuable confirmation of the belief previously entertained, that the continued production of milk by the European breeds of cows is a modified function in the animal economy, originating in an artificial habit kept up through many generations, and dependent upon a modification of structure which that habit has been the means of inducing.

That the various breeds of *sheep* at present domesticated in Europe, have had a common origin, is not doubted by any zoologist, notwithstanding the differences in their stature and proportions, the texture and colour of their wool, the presence or absence of horns, &c. The most marked deviation from the usual type is presented by a breed of Spanish sheep, distinguished by the length and straightness of the hair, and by the length and spiral twist of the horns. Various breeds are found in Asia and Africa, as to whose specific unity with each other, and with European sheep, zoologists are not agreed. We have a remarkable example of climatic variation, however, in the fact, that in the races spread through Persia, Tartary, and China, the tail seems replaced by a double spherical mass of fat, which forms a most awkward excrescence on the rump, and is nearly destitute of hair; whilst these sheep, transferred to the cold, dry pastures of Siberia, are affirmed by Ermann to lose this peculiar conformation in the course of a few generations. The sheep of Syria and Barbary, on the other hand, have an accumulation of fat in the tail itself, which is long, and sometimes attains a weight of from seventy to one hundred pounds. It is a curious and very significant fact, that the sheep of the Cape of Good Hope, which are descended from the European stocks, should exhibit the same tendency to the accumulation of fat about the rump, as is seen in the human races indigenous to that region. The sheep which were transported into South America by the Spaniards, have not multiplied so extensively as the oxen and swine; and from their more limited diffusion, we find, as might be expected, that they exhibit but a comparatively slight amount of variation. The remarkable change in the character of the hair, presented by the sheep in the West Indies has been already referred to. — Among sheep, as among other domesticated animals, new races are continually being produced by breeders, not merely by crossing or intermixing races already constituted and well known, but also by taking advantage of peculiarities which occasionally present themselves spontaneously, and using means to perpetuate these. The following is one of the most curious examples of this kind upon record. In the year 1791, a ewe on the farm of Seth Wright, in the state of Massachusetts, gave birth to a male lamb, which, without any known cause, had a longer body and shorter legs than the rest of the breed; the joints also were peculiarly formed, and the fore-legs crooked. The conformation of this animal rendering it unable to leap over fences, it was thought desirable to endeavour to propagate its peculiarities; and accordingly when it was fit for procreation, several ewes were impregnated by it. Out of the lambs first produced, only two presented the same peculiarities; more were obtained in subsequent years; and when they became capable of breeding with each other, the new race was completely established; its distinctive characters being uniformly presented when *both* parents possessed them, but tending to disappear when the sheep of the "ancon" or "otter" breed (as it is called) were allowed to breed with those of the ordinary type.* This fact, as we shall hereafter see, has an important bearing on the question of the *spontaneous* origination of permanent varieties, in the human or any other species that is disposed to undergo occasional modifications; which modifications, under ordinary circumstances, disappear as often as they recur. Thus it is not uncommon to meet with families distinguished by the possession of some peculiarity of feature, or by some well marked departure from the ordinary conformation, such as the possession of six fingers on each hand and six toes on each foot. If such were to intermarry exclusively with one another, there can be no reasonable doubt that the children would invariably exhibit the same peculiarity; and that the six-fingered race, which now tends, whenever it is originated, to merge in the prevailing five-fingered type, would then become permanent. When it is considered that the influence of a scanty population, in the early ages of the world, by isolating different families from each other, and causing inter-marriages amongst even very near relatives, would have been precisely the same with that which is now exercised by the breeders of animals, we see one reason why the varieties which *then* arose should have had a much greater tendency to perpetuation, than those which *now* occasionally present themselves.

In regard to the *horse*, it will be sufficient to observe that no zoologist has ever ex-

depends upon the adaptation between the constitution of the several races and the climates in which we find them, is deficient in solidity of foundation.

* See Col. Hutchinson's Memoir in the Philosophical Transactions for 1813.

pressed any doubt of the specific unity of all the domesticated breeds, or of their identity of origin with the so called "wild horses" of Northern Asia: which are probably descended from domesticated progenitors. Yet their diversities in stature, conformation, &c. are very considerable. Thus the ordinary height of the Shetland pony is from eight to ten hands; and individuals have been occasionally seen which were no more than seven. On the other hand, the draught horse commonly stands from sixteen to seventeen hands; and not unfrequently surpasses this height. In regard to the conformation of the skull, again, it has been remarked by Blumenbach, that there is more difference between the elongated head of the Neapolitan horse and the skull of the Hungarian breed, which last is remarkable for its shortness and the breadth of the lower jaw, than there is between the most dissimilar human crania. The differences in general constitution, also, as regards the power of sustained effort on the one hand, or of intense exertion for a short period on the other, are no less remarkable. But the breeds which are furthest removed from each other in these particulars are connected by such a gradual series of transitional forms, that there is no possibility of drawing a line between them; and, like the various races of dogs, sheep, &c., they freely intermingle with each other, and produce offspring which are as fertile with their own kind, as with either of the parent stocks. It has been, in fact, by such intermixture of the large and powerful races of Northern Asia with the lighter and more agile horses of Arabia and Barbary, that many of the European breeds have been obtained. The wild horses which at present range over the plains of Tartary differ from the domesticated races in several particulars; thus, as we are informed by Pallas, the cranium is relatively larger and more vaulted, the limbs are stronger, the back is less arched; their hoofs are smaller and more pointed; their ears are longer and bent more forward. Their habits, moreover, are peculiar; for they associate together in herds or troops to the number of several thousands, spreading abroad to feed, but congregating together on the appearance of danger, and seemingly putting themselves under the direction of a leader; on the approach of an enemy they close into a dense crowd, and, attacking the intruder, trample him to death; or, like many other gregarious animals, the females, the young, and the weak being placed in the rear, the stronger individuals array themselves in front, and fight most vigorously with their heels. Now these peculiarities of structure and habit are not only seen in the wild horses of Northern Asia, but also in those which have spread themselves over the extensive plains of South America, since their introduction into that continent by the Spaniards; and it is nearly certain that the former, like the latter, are the descendants of a domesticated stock, whose return to something like the original condition of the species, has reproduced (at least in some degree) the original instincts, which had been entirely subdued for a time by the influence of domestication. In the horse, as in the dog, we have evidence that the habits which are developed by human training may become, to a certain extent, hereditary. Thus, it is observed that the wild horse has no pace but the walk and the gallop; the trot, to which European horses are usually trained, is an acquired habit, yet it obviously "comes naturally" to the colt of a domesticated breed; and, in like manner, the peculiar pace to which the South American horses are trained (which is a kind of running amble, the two legs of the same side being moved forwards together) is used without any instruction by the offspring of those by whom it has been acquired. Another example of the transmission of acquired propensities in horses is mentioned by Mr. Knight: the Norwegian ponies have been taught to obey the *voice* of their riders rather than the bridle; and the English horse-breakers complain that it is impossible to produce the latter habit in the offspring of this race placed under their tuition, notwithstanding that they are exceedingly docile and obedient when they understand the commands of their master, as imparted by word of mouth. It is equally difficult, he adds, to keep them within hedges, owing, perhaps, to the unrestrained liberty to which the race may have been accustomed in Norway.

From the present condition and past history of the domesticated races of Mammalia, of which a general survey has thus been taken, some important inferences may be drawn, which it may be advisable to put in the shape of formal propositions; since in this manner we shall be able to define our terms more strictly, and to use these definitions as the foundation for our future investigations into the relationship of the several branches of the Human family.

1. *Races* of living beings are, properly, successions of individuals propagated from any given stock; and the term implies no more than the fact of the transmission of a distinctive character by descent.

2. Two races, distinguished by well-marked peculiarities, may rank either as distinct *species*, or as *varieties* of the same species; being supposed, in the first case, to be descended from parents which themselves originally exhibited the same peculiarities; and being considered, in the second, as the descendants of an identical, or, at any rate, of a similar, parentage.

3. The question of unity or diversity of species, between two races, cannot be decided by the degree of difference which exists between them; for the answer to it entirely depends upon the *constancy* with which the peculiarity (of whatever nature it may be) is transmitted from parent to offspring, and upon the amount of variation which is exhibited even within the acknowledged limits of the

respective races. And thus a character which is perfectly valid in one group, may be entirely inapplicable in another.

4. Two races can only be regarded as *specifically distinct*, when the characters which separate them are transmitted with complete uniformity from parent to offspring; when there are no intermediate gradations tending to connect them; and when no such tendency to variation has manifested itself in either race, as shall make it probable, or, at any rate, possible, that their differences may be the direct result of external influences, or may be attributed to an unusual divergence in the characters of the offspring from those of the parents.

5. On the other hand, two races may undoubtedly be regarded as *specifically identical*, when, however great the differences in stature, conformation, psychical character, &c., presented by their respective types, these types are connected with each other by intermediate gradations, so close as to render it impossible to establish a definite boundary-line between the collections of individuals which are assembled around them.

6. Again, two races may be undoubtedly regarded as *specifically identical*, when in either race *varieties* present themselves, which exhibit the distinctive characters of the other race; since we then have evidence, that, although these peculiarities are so *generally* transmitted from parent to offspring that each race possesses a certain degree of permanence, yet they are not thus *uniformly* inherited; and, consequently, there is nothing to prevent the transformation of the one race into the other, if the circumstances which have originated the variation, even in a single case, should act with sufficient potency on the whole mass.

7. No character can be safely adopted as justifying the assumption of the specific diversity of two races, which has been found by experience to undergo considerable modification in either race, even though such modification should not proceed to the extent of conversion into the character of the other; for if a limited amount of change in external conditions be found capable of effecting a certain degree of alteration, the probability is strong that the higher difference may have had its origin in the more potent operation of the same class of causes.

8. The very fact of the extensive dispersion of a race, and of its existence under a great variety of external conditions, implies a marked capacity for variation; since without such capacity, the race could not continue to flourish.

9. Among the conditions which most tend thus to produce *varieties*, within the limits of *species*, are those that are included under the general term *domestication*; and the widest divergence among these varieties is to be found in those species, which are brought into the closest relation to Man.

10. Among the domesticated races of quadrupeds, the characters most susceptible of variation are,— 1. *Stature*; — 2. *General conformation of the body*, as dependent upon the proportionate development of the limbs and trunk, the proportion of the breadth and thickness of bones to their length, the relative development of the soft tissues in different parts, &c. &c.;—3. *Conformation of the skull*, as shown especially in the relative development of the cranial and facial portions, the capacity of the cranial cavity, and the elongation of the muzzle; — 4. *Quantity*, *texture*, and *colour* of the *hairy covering*; — 5. *Psychical character*, as shown in the increase of *intelligence*, in the acquirement of new methods of action, and in the disappearance of some of the natural *instinctive* propensities.

11. In every race of domesticated animals, new varieties, departing more or less from the parent stock, in one or more of these characters, are occasionally produced; some of these being directly traceable to the influence of external conditions, whose action upon a long succession of generations gradually modifies the character of that part of the race which is exposed to it; whilst others originate in the production of offspring, which, from some cause not understood, present a marked departure from the parental type. In the first case, the variety is *permanent*, that is, it tends to hereditary transmission so long as the same conditions exist; and thus arise the peculiar adaptations between the characters and constitutions of races, which have been dispersed through regions very dissimilar in their physical conditions, and the climate, food, &c., to which they have been respectively habituated. In the second case, the variety is *transitory*, the individual peculiarity tending to disappear in the course of two or three generations, by becoming merged in the more general type; but if it should happen that the individuals thus distinguished should breed together, the peculiarity shows a tendency to perpetuation by hereditary transmission; and thus an entirely new race may originate, which remains distinct so long as it is not allowed to breed with others.

12. The several races of any kind of domesticated animals, which, according to the foregoing criteria, are accounted as belonging to the same species, breed freely and spontaneously with each other, when allowed to do so; and the offspring are fertile, not only with either of the parent races, but with each other. The mixed races thus originating, it may be added, frequently surpass either of their parent stocks, not only in the advantageous combination of different attributes, but also in general vigour, and in procreative capacity; so that the mixture of races which are specifically identical, tends to the multiplication of the species as a whole.

13. On the other hand, although propagation *may* take place between individuals of undoubtedly distinct species, yet there is little spontaneous tendency to such admixture; for each animal will select one of its own species for sexual intercourse, in preference to one of another species; and it is, con-

sequently, only when restricted by artificial interference, that a male and a female of different species are disposed to copulation with each other. The hybrid offspring of this act partake of the characters of both the parent stocks, but are deficient in generative power; so that, although a mule may be fertile when paired with an individual of either of the parent races, it is seldom or never fertile with one of its own kind. Thus the peculiarities introduced by hybridity are speedily merged into those of the parent stocks; and no new race has ever been *known* to originate from this kind of union.*

14. Among all those races which are entitled to rank as *varieties* only, the *physiological* conformity is often closer than the structural; thus, as Dr. Prichard has pointed out "the great laws of the animal economy, all the principal facts which relate to the natural and vital functions, the periods and duration of life, the economy of the sexes, the phenomena of parturition and reproduction, are, with slight deviations resulting from external agencies, constant and uniform in each particular species."

15. So, again, among the varieties of the same species, there is, with subordinate differences, such as can be traced to external agencies, and particularly to human influence, a very close *psychical* conformity; the capacities of the several races being fundamentally the same, although varying in their degree of relative development.

III. General Survey of the Diversities, in Physical and Psychical Characters, presented by the different Races of Mankind.

If it were possible to bring together under one view, characteristic examples of every type of Human conformation which the progress of Ethnological research has hitherto made known, it would be found that they all accord in the peculiarities by which Man has been shown (Sect. 1.) to be distinguished from even the highest of the Quadrumanous order; and that, notwithstanding a certain amount of approximation which is presented to that order in the aspect of certain human countenances (*figs.* 803, 804, 805.), and even in the habits of life of certain tribes, yet the essential and fundamental

Fig. 803.

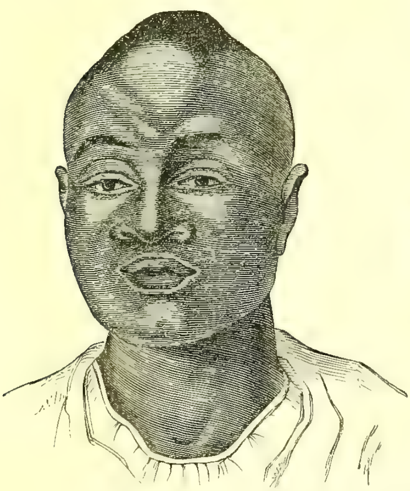
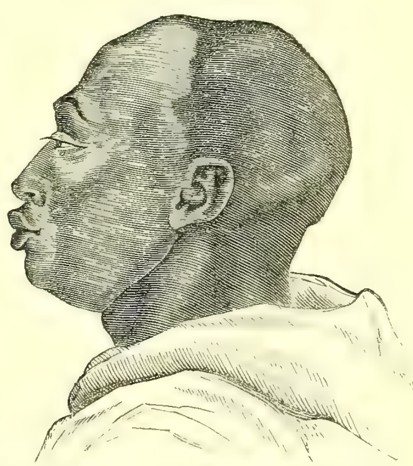


Fig. 804.



Negro of Bournou. (*From a portrait taken under the direction of Prof. Milne-Edwards.*)

points of difference are never obliterated. But among these types we should find so wide a diversity, that we should naturally be led to question their relationship to each other and to ourselves; and should seek to determine whether these differences are inherent and unalterable in each race, so as to forbid the idea of any essential modification, either in the past or the future, from the influence of external circumstances; or whether there is any probable evidence that they may have been produced by those external agencies, which we have seen to possess such a remarkable power of altering the conformation, and even the instinctive propensities, of domesticated animals. Such is the first question which we should have to answer; and in a *practical* point of view, as influencing our conduct towards the races which differ more or less widely from our own, it is undoubtedly the most important. But the physiologist and the zoologist seek to attain a more positive *scientific* determination of this relationship; and since, if such a determination

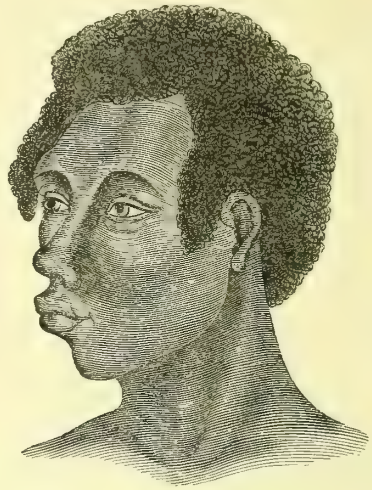
* It is not quite certain whether mule or hybrid Animals have ever produced fertile offspring when matched with each other; but it is quite certain that if a *second* generation of hybrids has thus been engendered, a *third* has never been, the race having no capacity for perpetuation. Among Plants, the limits are wider, a *third* and even a *fourth* generation having been thus sometimes produced; but there is obviously a want of fertility, and a consequent tendency to extinction, in all hybrid races whose parents are specifically different.

can be attained, the practical question is at once and completely settled, we shall apply ourselves to the search for it, as fully as our present limits permit.

Fig. 805.

Tasmanian female. (*From the* "*Atlas du Voyage de l'Astrolabe.*")

Fig. 806.



Aramanga youth. (*From a portrait in Dr. Pickering's* "*Natural History of Man.*")

What, then, is the true zoological relationship between these different races, so dissimilar in colour, features, bodily conformation, stature, habits of life, and moral and intellectual cultivation? Have we any ground to consider them as *distinct species?* or are we to regard them as *varieties of one and the same species?* Are the fair Circassian and the jet-black African, the olive Malay and the red American, the dusky New Zealander and the florid Saxon, all of one original stock? Did the Patagonians, whose average height is nearly six feet, spring from the same parents with the pigmy Bosjesmans, whose usual height is under five, that of the females rarely much exceeding four? Are the fat, blubber-fed, flat-visaged Esquimaux even most distantly related to the lean, date-eating, hatchet-faced Arab? "Does the Bosjesman, who lives in holes and caves, and devours ants' eggs, locusts, and snakes, belong to the same species as the men who luxuriated in the hanging gardens of Babylon, or walked the olive-grove of Academe, or sat enthroned in the imperial homes of the Cæsars, or reposed in the marble palaces of the Adriatic, or held sumptuous festivals in the gay *salons* of Versailles? Can the grovelling Wawa, prostrate before his fetish, claim a community of origin with those whose religious sentiments inspired them to pile the prodigious temples of Thebes and Memphis, to carve the friezes of the Parthenon, or to raise the heaven-pointing arches of Cologne? That ignorant Ibo, muttering his all-but inarticulate prayer, is he of the same ultimate ancestry as those who sang deathless strains in honour of Olympian Jove, or of Pallas Athenè; or of those who, in a purer worship, are chanting their glorious hymns or solemn litanies in the churches of Christendom? That Alfouro woman, with her flattened face, transverse nostrils, thick lips, wide mouth, projecting teeth, eyes half closed by the loose swollen upper eyelids, ears circular, pendulous, and flapping; the hue of her skin of a smoky black, and, by way of ornament, the septum of her nose pierced with a round stick some inches long, —is she of the same original parentage as those whose transcendent and perilous beauty brought unnumbered woes on the people of ancient story, convulsed kingdoms, entranced poets, and made scholars and sages forget their wisdom? Did they all spring from one common mother? Were Helen of Greece, and Cleopatra of Egypt, and Joanna of Arragon, and Rosamond of England, and Mary of Scotland, and the Eloisas, and Lauras, and Ianthes, — were all these, and our poor Alfouro, daughters of her who was 'fairest of all her daughters, Eve?' The Quaiqua or Saboo, whose language is described as consisting of certain snapping, hissing, grunting sounds, all more or less nasal,—is he, too, of the same descent as those whose eloquent voices 'fulmined over Greece,' or shook the forum of Rome, or as that saint and father of the church surnamed the 'golden-mouthed,' or as those whose accents have thrilled all hearts with indignation, or melted them with pity and ruth, in the time-honoured halls of Westminster?"*

This question is capable of being considered under a great variety of aspects. There are many very excellent persons, who think it quite sufficiently answered by the authority of the Scriptural narrative, and who maintain that to this authority all opposing considerations

* From an Introductory Lecture, entitled "Our Institution and its Studies;" by Dr. J. A. Symonds. Bristol, 1850.

must give way. But, on the other hand, the conviction is now fast spreading among enlightened thinkers, that the Scriptures are no more intended to teach men Ethnology than to instruct them in Geology or Astronomy; and that the former, like the latter, is a legitimate object of scientific investigation, and should be pursued without fear as to the results. Any attempt, in fact, to fetter the scientific inquirer by the supposed authority of inspiration, is certain to damage the latter in the estimation of the most intelligent part of mankind; for, as has been well remarked by a very orthodox theologian, Dr. Henry More, "the unskilful insisting of our divines upon the literal sense of Moses has bred many hundred thousands of atheists." But even those who profess to place the most implicit confidence in the declarations of the Scriptures, as to the common origin of all the races of mankind, do, in effect, get rid of all the force of these declarations, when it suits their purpose to do so, by the mode of interpreting them which they adopt. They assert that the *Adamic* race does not include the barbarous inhabitants of remote regions; and that Negroes, Hottentots, Esquimaux, and Australians are not, in fact, *men* in the full sense of the term, or beings endowed with mental faculties similar to our own. They contend that these and other uncivilised tribes are inferior in their original endowments to the proper *human* family, which supplied Europe and Asia with inhabitants; and that, being organically different, they are separated by an "impassable barrier" from the race which displays in the highest degree all the attributes of humanity, and can never be raised to an equality with it. They maintain that the ultimate lot of the ruder tribes is a state of perpetual servitude; and that if, in some instances, they should continue to repel the attempts of the civilised nations to subdue them, they will at length be rooted out and exterminated from every country on whose shores Europeans shall have set their feet.

Now if the distinct origin of these tribes be admitted, — if we are to regard the Negro and Australian, not as our fellow-men, brethren of the same great family as ourselves, but as beings of an inferior order, — and if duties towards them were not contemplated, as we may in that case presume them not to have been, in any of the positive commands on which the morality of the Christian world is founded, our relations to those tribes will appear not to be very different from those which we might consider ourselves to hold towards the higher races of brutes. If such races be not *men*, then the golden rule, "Whatsoever ye would that men should do unto you, do ye even so unto them," is not applicable to our intercourse with them. We can scarcely imagine a Grotius or a Puffendorf, or any other great jurist, attempting to determine the *jus belli* or *pacis* between ourselves and a tribe of orangs, who had just sense enough to pass for men, and began to be suspected of the cheat, — which is nearly the true character of the Negroes, if those are right who maintain the doctrines just alluded to. And we may go a step further, and assert that there is, in such a case, no moral principle which should prevent a hungry wanderer in Negroland or Australia from satisfying his appetite, by killing and eating the first native he might happen to meet.

Thus, then, the widest extremes of opinion, and the greatest diversity in those rules of conduct which are founded upon such opinions, may exist among those who profess the most implicit reverence for the scriptural *dictum*, that "God hath made of one blood all nations of men, for to dwell on all the face of the earth." For, whilst some include under the term "men," all the individuals grouped together by the naturalist under the *genus homo*, and regard this genus as consisting of but a single *species*, of which the several races are only to be ranked as varieties, others assert that this genus includes several species, which form a gradual transition from the highest and most cultivated races of mankind, to those degraded races, which (as they affirm) have more in common with the brutes; the former alone being really entitled to the appellation *men*, whilst the latter should be called by some other name indicating their close affinity to chimpanzees and orangs. Thus we are thrown back upon scientific inquiry, as the only legitimate means of bringing this question to an issue; and such an inquiry can only be rightly pursued, when it is prosecuted upon the broadest possible basis, and is made to comprehend every kind of information which can be brought to bear upon it. Nothing can be easier than to bring together an *ex parte* collection of facts, which shall give to either doctrine, — that of the *specific unity*, or that of the *specific diversity*, of the human races, — an apparently fair claim to reception. But since both cannot be true, and since the question can only be decided by the balance of probabilities, no evidentiary fact having any relation to the subject ought to be left out of view; and thus the science of Ethnology must be built upon the foundation afforded by numerous other departments of scientific inquiry. The *anatomist* examines the configuration of the body, and compares the peculiarities of the various tribes, with the view of determining how far structural differences prevail over resemblances, and of ascertaining whether these differences possess that constant and untransitive character, which the naturalist requires as a justification of specific distinction. The *physiologist* searches into the history of the vital functions in the several types of humanity, and seeks for information with regard to the permanence of anatomical differences, the effects of external agencies in modifying the configuration or constitution of the body, and the tendency to spontaneous variation in the forms presented by individuals, families, or tribes, known to be of the same stock. The *psychologist* has a most interesting subject of investigation, in the study of the psychical constitution of the several races, and in the extraction (so to speak) of their respective mental and moral characters, from their habits of life, their languages, and their religious observances. It is his business to inquire how far one common psychical character can be inferred from such diverse manifestations; that is, how far the differences which he cannot but observe in intellectual capacity, and in moral and even instinctive tendencies, are fixed and permanent, or are liable to spontaneous variation, or to alteration from the modifying influence of education and other external conditions. The *physical geographer* lends his aid, by bringing to bear upon the inquiry his knowledge of the outward circumstances under which these variations in bodily and mental constitution are most constantly found. And it is from the materials which he contributes, that the physiologist and the anatomist have to determine the degree in which these circumstances can be justly considered as the causes of variation; and, more especially, whether the coincidences between particular bodily configurations or mental constitutions, and certain combinations of climatic and geological conditions, are the result of induced differences among the human races which are respectively subject to the latter, or are to be attributed to the implantation of originally dissimilar stocks in the respective localities in which their descendants are now found. But in order to carry on these researches, the information of the *historian* is continually needed, on the actual descent, migrations, conquests, &c. of the nations whose physical and mental characters we are comparing. The question of the fixity of all or any of the characters by which the races of mankind are at present distinguished from each other, requires for its solution a comparison of the present with the past. No valid proof of their permanence can be drawn from the limited experience of a few generations; and no evidence of change can be reasonably looked for, except under the long-continued agency of modifying causes. The required information is sometimes supplied by direct historical testimony; but this is frequently insufficient, and recourse must be then had to the *philologist*, who derives from the comparative study of the languages of different tribes, most important evidence as to their degree of filiation, and thus extends, combines, and confirms the indications, which the historian had drawn from other sources. Independent of the aid which philological research affords to other departments of ethnology, it directly bears upon the great problem of the unity or identity of mankind; for it not only answers a common purpose with historical testimony, in establishing the genealogical relations of tribes long since dispersed from their original centres, and separated at present by strongly-marked physical and psychical differences; but it also affords important evidence as to the fundamental *similarity*, if not *identity*, of the primitive stocks.

It is obviously impossible to enter at any length into any one of these topics of inquiry, within the limits of the present article; and all that will be here attempted, will be to place before the reader a general *résumé* of the whole subject, carrying out those portions into somewhat more of detail, in which the anatomist and physiologist are most concerned.

The question at issue has usually been considered under the simple aspect of *specific unity* or *diversity*; — that is, in the *first* place, whether all the existing races may be supposed to be the descendants of *one pair* of "protoplasts;" all their diversities in physical conformation, in language, in mental character, and in social condition, having since arisen; — or whether, *secondly*, the existing races must be regarded as having sprung from *several distinct pairs* of protoplasts; which originally presented differences amongst themselves, nearly the same with those which now exist amongst the races that seem most remote from each other. Now the first of these suppositions requires that evidence should be given of a very considerable amount of *variability* from the original type (whatever that may have been) amongst the descendants from the common ancestry: whilst the second is based on the idea, that the leading characters which now separate the different races are *permanent*, and must have been presented by their original progenitors. A *third* supposition, which has been put forward within the last few years, regards the existing races as *not* all proceeding from *one* pair of "protoplasts," but from *several;* but considers that these, though scattered over the globe, were *fundamentally similar* in corporeal and mental constitution, and differed only in the adaptation of certain of their physical characters to the different circumstances of their several abodes, — thus being all comprehensible within the limits of one species, — and all possessing, too, a certain capacity for variation, which has been manifested in the production of subordinate diversities, and has even proceeded, in some instances, under the prolonged influence of change of climate, civilization, &c., to soften down, if not entirely to obliterate, the original differences. On the general bearing of the last of these hypotheses, a few remarks seem called for.

Although the same affinity or blood-relationship would not exist between the descendants of several distinct pairs of "protoplasts," as between those of a common ancestry, yet the moral relations between them would be as close as on the supposition of their consanguinity. For, as has been justly observed, "the moral rights of men depend on their moral nature; and while Africans have the hearts and consciences of human beings, it could never be right to treat them as domestic cattle or as wild fowl, if it were ever so abundantly demonstrated that their race was but an improved species of ape, and ours a degenerate kind of god."* This view has recently been very forcibly

* New Quarterly Review, No. XV. p. 131.

urged by Professor Agassiz, who has adopted in regard to the human races the same views as he has put forth with respect to many other species (p. 1310.); and who thus upholds the "unity of mankind," whilst contending for the diversity of "protoplasts."

"We recognise," he says, "the fact of the unity of mankind. It excites a feeling that raises men to the most elevated sense of their connection with each other. It is but the reflection of that Divine nature which pervades their whole being. It is because men feel thus related to each other that they acknowledge those obligations of kindness and moral responsibility which rest upon them in their mutual relations. And it is because they have this innate feeling, that they are capable of joining in regular societies, with all their social and domestic affinities. This feeling unites men from the most diversified regions. Do we cease to recognise this unity of mankind, because we are not of the same family, because we originate in various countries, and are born in America, England, Germany, France, Switzerland? Where the relationship of blood has ceased, do we cease to acknowledge that general bond which unites all men of every nation? By no means. This is a bond which every man feels more and more, the farther he advances in his intellectual and moral culture, and which in this development is continually placed upon higher and higher ground; so much so, that the physical relation arising from a common descent is finally entirely lost sight of, in the consciousness of the higher moral obligations. It is this consciousness which constitutes the true unity of mankind." This unity, he continues, may become a yet stronger bond of moral affinity, than that afforded by community of descent. "Where men of the same nation, individuals whose studies, whose calling in life have developed in them the same faculties, the same feelings, are brought closely together, relations spring up between them so intimate as by far to outweigh the natural bonds which a common parentage may establish between men. Such individuals do not feel themselves to be near each other, do not sympathise in their aspirations, do not join in the same purposes, *because* they are brothers, because they belong to the same family, because they are of the same nation; but because they feel that they are men, and that the natural dispositions wherewith they are endowed as men are developed in them in a similar manner, and with reference to the same great human interests. Is there any one who would consider the ties between two such individuals on that intellectual and moral ground, as lessened because they may not be physically related at all? or who would consider the differences in their physical features as an objection to their being more intimately connected than other men who in features resembled them more, or are related to them more closely, perhaps by the nearest ties of blood? We can therefore take it as a matter of fact, that, as we find men actually living together in the world, it is not the physical relation which establishes the closest connection between them, but that higher relation arising from the intellectual constitution of man." Professor Agassiz then refers to various departments of Natural History, as affording proof "that the closest and most intimate unity may exist without a common origin, without a common descent, without that relationship which is often denoted by the expression 'ties of blood.' On the other hand, that these ties of blood may exist, without necessarily calling forth the higher connections which may be found between individuals of the same type, is, alas! too plainly shown by the history of mankind. The immediate conclusion from these facts, however, is the distinction we have made above, that to acknowledge a unity in mankind, to show that such a unity exists, is not to admit that men have a common origin, nor to grant that such a conclusion may be justly derived from such premises. We maintain, therefore, that the unity of mankind does not imply a community of origin for men; we believe, on the contrary, that a higher view of this unity of mankind can be taken, than that which is derived from a mere sensual connection; that we need not search for the highest bond of humanity in a mere animal function, whereby we are most closely related to the brutes."*

The *Anatomical* differences by which the several races of Mankind are distinguished from each other, may be referred to the following heads: —

1. Conformation of the cranium.
2. Conformation of the pelvis.
3. Conformation of other parts of the skeleton.
4. Colour of the skin.
5. Colour, texture, and mode of growth of the hair.

By most writers on the diversities of mankind, the varieties which are observable in the conformation of the bony skeleton, and particularly in that of the cranium and pelvis, have been thought to furnish distinctive characters of more importance than those derived from the colour of the skin, or the texture of the hair; since, while a certain capability of alteration in the latter, under climatic influences, can scarcely be gainsayed, it might be supposed, *à priori*, that strongly marked peculiarities in the configuration of the skull, in the proportion of the parts of the body, and in the development of the brain, would be less likely to undergo alteration. Special attention will be here bestowed, therefore, upon the first three of this series of characters.

1. *Conformation of the Cranium.* — In estimating the degrees of diversity presented by the skulls of various races, it is absolutely necessary that some definite method of comparison should be fixed upon. The first attempt of this kind of which we have any account, was made by Camper; who main-

* Christian Examiner, Boston, N.E. Jan. 1850.

tained that the *profile* view is the most characteristic, and that the "facial angles" of the different races vary so greatly and so constantly, that upon this character alone a valid distinction might be founded. By Blumenbach, on the other hand, it was considered that the comparison of the breadth of the head, particularly as seen in the *vertical* aspect, is the method by which the most strongly-marked differences are brought into view. By Professor Owen the importance of the *basal* aspect has been especially dwelt upon, in his comparison of the skulls of the higher Quadrumana with that of Man, as more fully indicating the relative proportions and extent, and the peculiarities of formation, of different parts of the cranium, than any other method. By Dr. Pritchard, again, the importance of the front or *facial* view has been clearly shown, in regard, at least, to one variety of cranial conformation. Lastly, by Prof. Retzius, the *length of the cranial cavity in proportion to its breadth* is considered as the character of greatest importance; this being regarded by him as indicative of the relative development of the posterior lobes of the cerebral hemispheres, and of the degree in which they cover-in, or extend beyond, the cerebellum. As we have already seen, the superior development of these posterior lobes constitutes a marked difference between the cerebrum of Man and that of the higher Quadrumana; and in this respect it would appear from the evidence afforded by cranial conformation *, that there is a marked difference among the several races of mankind.

The only method of comparison which can be fairly relied on, is that in which *all* the points of difference are taken into account; and as this has been done more fully by Dr. Prichard than by any other ethnologist, his arrangement will be taken as the chief guide in the present instance.—If we were to select from a large collection of human crania, brought together from all quarters of the globe, those which differed most widely from each other, and which might, therefore, be considered as *types* of certain peculiarities of conformation, and if we were then to compare these more closely, so as to eliminate those which might be regarded as presenting mixtures or combinations of the most divergent types (just as in studying the solar spectrum, the optical investigator eliminates all the colours which can be generated by admixture, and leaves only the three *primaries*, red, blue, and yellow), we should find ourselves reduced at last to *three* forms, which would probably be the crania — (1) of a Negro of the Guinea coast, or of a Negrito of Australia, (2) of a Mongolian or Tungusian of Central Asia, or of an Esquimaux or Greenlander, — and (3) of a native of Western or Southern Europe. The most marked feature of the first of these would be the projection of the jaws; hence this type is called by Dr. Prichard the *prognathous*. That of the second would be the breadth and flatness of the face, which, with the narrowness of the forehead, gives to the facial aspect somewhat of a *pyramidal* form, which is the designation applied to this

Fig. 807.

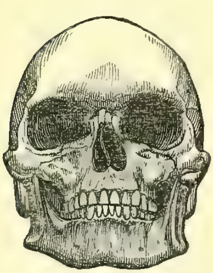


Fig. 808.

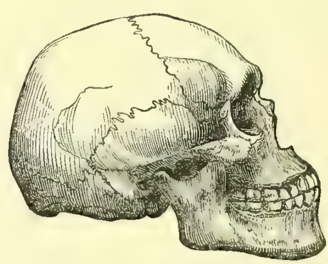


Fig. 809.

Prognathous Cranium of a native Australian of the Western Port tribe. (From a specimen in the Museum of the Royal College of Surgeons.)

type by Dr. Prichard. The third form would not be distinguished by any particular features so much as by an absence of the longitudinal projection of the first, or the lateral projection of the second, and by a general symmetry of the whole configuration, which may be characterised as *oval* or *elliptical;* such being the form presented when the cranium is viewed either facially, basally, or vertically. The distinctive characters of these three types will now be more particularly considered; and the European type may be conveniently taken as the standard of comparison, since it is in many respects intermediate between the two others; one of these departing from it in one direction, and the other in the opposite.

* The author would remark, however, that this evidence cannot by any means be implicitly relied on; since the relative positions of the different parts of the encephalon may vary, without a corresponding alteration in their development, as is seen when the form of the cranium has been altered by compression. Of the fallacy of inferences drawn from an inspection of the cranium, as to the development of the different parts of the encephalon, we have an example in the assertion of Gall, that castration occasions atrophy of the cerebellum; a statement which has been completely negatived by the observations of Leuret.

Of the Prognathous type. — The most marked feature of the typical prognathous skull, as already remarked, is the prominence of the jaws, as seen in profile (*fig.* 807). It is this which gives to the features of the Negro and Australian their peculiar ugliness; and it is on this that the difference of the facial angle between the Negro and the European chiefly depends. In both jaws we observe that the alveolar ridges project in such a manner, that the front teeth implanted in them meet at an angle, instead of being in the same, or in parallel planes, as in those skulls which are termed for the sake of distinction, *orthognathic.* Independently of the projection of the muzzle, however, there is an appearance of general elongation of the cranium from back to front, so that the antero-posterior diameter of the cranial cavity is greater in proportion to the lateral, than it is in the oval cranium. Thus the average *length* of ten Negro skulls measured by Professor Van der Hoeven*, was 6·96 inches, while their average *breadth* was 5·11 inches; so that the relation of their length to their breadth was as 1·36 to 1·00. On the other hand, the average *length* of twenty European skulls was 7·04 inches, and their *breadth* 5·47 inches; so that the relation of their length to their breadth was 1·30 to 1·00. But this difference (which is by no means great) seems to depend rather upon the relative narrowness, than upon the elongation, of the Negro cranium; for it will be observed that its *absolute* length is less than that of the European, and that the difference in the dimensions of the two consists chiefly in the inferior breadth. The form of the whole cranium suggests the idea of lateral compression. The temporal muscles cover a large surface, and rise high upon the parietal bones; and the zygomatic arch has a large opening, but this is given by a forward rather than a lateral projection of the cheek bones. Although the forehead very commonly recedes in the prognathous skull, this is by no means a constant character (*fig.* 810); even where it is high, however, it is seldom or never broad or full. The position of the foramen magnum has been affirmed to be, in the Negro, so far behind the nearly central place which it holds at the base of the European skull, as to constitute a marked character of approximation to the quadrumanous type; but it has been shown by Dr. Prichard, that, when due allowance is made for the projection of the alveolar processes, the position of the foramen magnum in the Negro is as central as in the other races†, its anterior border being immediately behind the transverse line bisecting the antero-posterior diameter of the base of the cranium. The height of the Negro skull seems to be rather less than that of the European; but there is a more marked inferiority in the *capacity* of the Negro cranium, as shown by the length of the vault over the vertex, and in

Fig. 810.

Young Negro of Benguela. (*After Rugendas.*)

the circumference; for the former averaged, in the measurements of Professor Van der Hoeven, 13·81 inches in the Negro, and 14·67 inches in the European; whilst the average of the latter was 19·75 inches in the Negro, and 20·51 in the European. Although Professor Tiedemann attempted to prove*, by filling the cranial cavity with millet-seed, and then weighing the quantity which it was found to contain, that the capacity of the Negro's cranium is equal to that of the European's, yet, as Professor Van der Hoeven has pointed out, the average capacity of the Negro skulls thus examined by Tiedemann was about one-twentieth less than the average capacity of European skulls. On the other hand, the facial portion of the prognathous skull is relatively, and even absolutely larger. It has been usually described as being characterised by the large relative size of the parts subservient to the organs of the senses; but although it certainly appears that both the anterior and posterior nares are wider than in the European, that the nasal cavity is altogether more capacious (so as to allow a more extended surface for the distribution of the olfactive nerve), and that the external auditory meatus is remarkably large, it does not appear that the same holds good of the orbits, which, though sometimes larger, are sometimes smaller than in the average of Europeans.†

This prognathous type, although most remarkably developed among the Negroes of the Delta of the Niger, is by no means confined to them, nor to the African races in general, of which it is usually regarded

* Bijdragen tot de Natuurlijke Geschiedeniss van den Negerstam; Leiden, 1842.

† See Physical History of Mankind, vol. i. p. 290.

* Das Hirn des Negers, mit dem des Europäers und Orang Outangs verglichen. Heidelberg: 1837.

† See Prichard, op. cit. p. 292.

as characteristic. It is met with among inhabitants of various quarters of the globe; but is nearly always associated with squalor and destitution, ignorance and brutality. Instead of following an agricultural or pastoral life, the people among whom it prevails are, for the most part, hunters, or inhabitants of low marshy forests, dependent for their supplies of food upon the chase, or upon the accidental produce of the soil, and but little advanced in any of the arts which are characteristic of civilisation. Such is the character of those aborigines of Australia, and of certain islands of the Polynesian Archipelago, amongst whom the prognathous type is presented almost, if not quite, as characteristically as among the Negroes of the Guinea coast.

The skulls of some of these inferior races have been asserted by Dr. John Neill * to present a division of the articulating surface of each occipital condyle into two facets, by a groove or ridge; which appears to be the persistent indication of the fissure that originally separates the basi-occipital bone from the ex-occipitals. This character, however, is far from being constant in any one family. Thus it was only found in 30 out of 81 African crania; whilst it presented itself in only 4 pure Egyptian heads in Dr. Morton's collection, in 3 out of 105 skulls of aboriginal Americans, and in none of the other 129 skulls of different nations whose history was well known. Thus, although more common among the African races than in the others, and marking in them (like the occasional persistence of the separate intermaxillary bone to a later period than usual) a less complete development, yet its presence in but little more than one-third even of the Negro-crania, and its occasional existence elsewhere, altogether destroy its title to be considered a mark of separation between different branches of the human family. The writer has looked for this character in at least twenty African crania, without once meeting with it; the only skull which unequivocally presented it being that of a Tasmanian female, æt. 14.—Dr. Neill points out, also, that the lower boundary of the anterior nares in the Negro skull wants the sharp edge which is found in the higher races; and that this, also, may be regarded as a retention of the fœtal type. This character, however, is at least as strongly marked in Australians as in Negroes; and an approximation to it is shown wherever there is a tendency to the prognathous conformation.

Of the pyramidal type. — The most striking feature in this type of cranial conformation, which is best seen in the front and basal views (*figs.* 811. 813.), is the lateral or out-

Fig. 811.

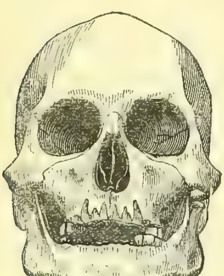


Fig. 812.

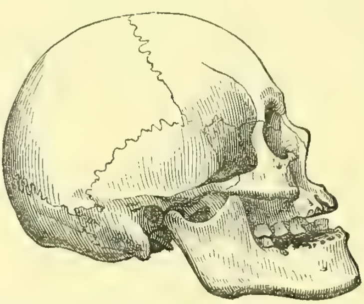
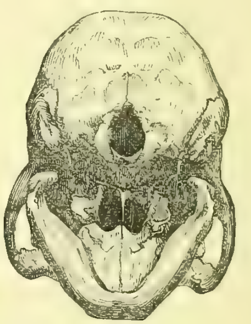


Fig. 813.



Pyramidal Cranium of Mongolian race. (From a specimen in the Museum of the Royal College of Surgeons.)

ward projection of the zygomatic arches; this is principally due to the peculiar form of the malar bones, whose facial surface is very broad and flat; but partly, also, to that of the zygomatic process of the temporal bone, which forms a large rounded sweep. From this peculiarity, in conjunction with the narrowness of the forehead, it results that lines drawn from the zygomatic arches, touching the temples on either side, instead of being parallel, or nearly so, as amongst Europeans, meet at no great distance over the forehead, so as to form, with the line joining their bases, a triangular figure. The upper part of the face being remarkably flat, the nose also being flat, and the nasal bones, as well as the space between the eyebrows, being nearly in the same plane with the cheek-bones, the triangular space bounded by these lines may be compared to one of the faces of a pyramid. This, however, is by no means the most important peculiarity of this type; for the shortness of the antero-posterior diameter of the cranium, in relation to the lateral, is, as pointed out by Professor Retzius, at least equally characteristic. Thus the average length of sixteen Laplander's skulls measured by him was about 6·90 inches, while the average breadth was as much as 5·78 inches; making the proportion of the former to the latter no more than 1·20 to 1·00. The greatest longitudinal dimension among all these skulls was only 7·08 inches, while the greatest lateral extension was as much as 6·16 inches; thus reducing the proportion to 1·15 to 1·00.

* American Journal of the Medical Sciences, Jan. 1850.

The orbits in these skulls are large and deep; and the peculiar conformation of the bones which surround them give to the aperture of the lids an appearance of obliquity, the inner angle being directed downwards (*fig.* 814).

Fig. 814.

Portrait of one of the "Siamese Twins." (*Taken in Paris in* 1830.)

The whole face, instead of approaching the oval, as in Europeans, is of a lozenge-shape; and the greater relative development of the zygomatic bones, and of the bones of the face altogether, when compared with the capacity of the cranium, indicate in the pyramidal skull, as in the prognathous, a more ample development of the organs immediately subservient to sensation; the lateral expansion being attended with a similar result in this respect, to that which is consequent upon the forward prolongation of the prognathous skulls. In the breadth of the lower jaw (*fig.* 813) a remarkable contrast will be noticed with that of the prognathous type (*fig.* 809). The greater part of the races representing the pyramidal type in a well marked degree, may be designated as pastoral nomades; some of them wandering with their flocks and herds over the vast plains of high Asia, whilst others creep along the shores of the Icy sea, supporting themselves partly by fishing, but living in part upon the flesh of their rein-deer. As in the preceding case, however, the same type is encountered in a remote quarter of the globe, among tribes whose descent would seem to be altogether different, yet which closely corresponds with the nomadic races of high Asia as to the physical conditions under which they live; namely, the Hottentots of South Africa, whose resemblance to Mongolians in cranial conformation, as well as in complexion, hair, and several other characters, is so striking as to have been noticed by all travellers familiar with both, and to have given rise to many speculations as to their possible blood-relationship. It will be hereafter shown, however, that there is no valid reason for separating the Hottentots from the general mass of the African nations; and just as the Australians repeat the prognathous type at a distance from its chief centre, with a slight admixture of the pyramidal, so do the Hottentots in some degree repeat the pyramidal, with an admixture of the prognathous.

Of the Oval or Elliptical type. — This form of cranial configuration at once approves itself to the educated eye, as distinguished by its symmetrical contour; neither the muzzle nor the zygomatic arches having an undue prominence, whilst, on the other hand, there is no appearance of flattening or compression. The cranium, in its fullest development, may be said to have the *length* of that of the Negro with the *breadth* of that of the Mongolian; and it is particularly distinguished by the lateral fulness, as well as by the elevation, of the forehead. This will be especially apparent on the comparison of *fig.* 815 with

Fig. 815.

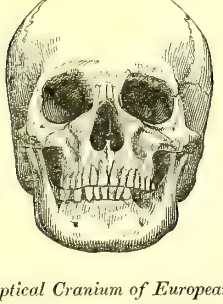


Fig. 816.

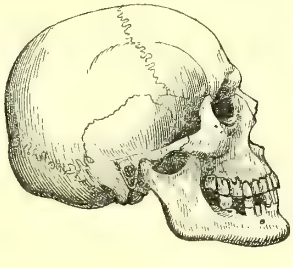


Fig. 817.

Elliptical Cranium of European. (*From a specimen in the Museum of the Royal College of Surgeons.*)

the corresponding view in *figs.* 807. and 811.; for in the former it will be seen that the breadth continues to increase above the orbits, and that the cranial vault is rounded and capacious; whilst in the other two, the breadth diminishes rapidly, especially in the frontal region, from the floor of the orbits upwards. The form of the zygomatic arches is such, that in the facial view they do not project laterally beyond the general boundary line, as they do in the Mongolian; whilst the conformation of the jaws is such, that they do not form nearly as great a projection beyond the ellipse which would include the whole cranium and the greater part of the face, when seen in profile, as they do in the Negro. Owing to the more perpendicular direction of the alveolar processes, the front teeth of the two jaws are fixed in planes which are nearly or quite parallel to each other. The chief positive distinction of this form of cranium, is the large development of the cranial cavity, and especially the fullness and elevation of the forehead, in proportion to the size of the face; indicating the predominance of the intellectual powers over those merely instinctive propensities which are more directly connected with sensations. Among European nations, the Greeks have probably displayed the greatest symmetry in the form of the head, in the largest proportion of individuals; but examples of equal symmetry might be found amongst any of the great group of nations now termed Indo-Atlantidæ, and even, as will hereafter appear, in nations of entirely different descent. Nearly all of these have acquired a certain amount of civilisation, living by agriculture, and possessing settled habitations; and among them, or among the offsets which have proceeded from them (as the people of the United States), we find all the nations which have been most distinguished for intellectual advancement, for the successful cultivation of the fine arts, and for the various improvements which distinguish the state of civilisation from that of barbarism.

To the foregoing general account of the three principal types of cranial conformation, may be added the results of the observations recently made public by Dr. Morton *, as to the capacity of the cranium of different races, measured after the manner adopted by Tiedemann (p. 1321.). The number of crania examined was 623; and they were derived from various races and families, as shown in the following table, which is here given without modification, although the writer (as will hereafter appear) is far from agreeing with Dr. Morton in the classification of these varieties which he has adopted.

It appears from this comparison, that the Teutonic race, and the nations chiefly derived from it, take the highest rank among those examined in regard to cranial capacity; whilst the lowest is occupied, not by the Negroes, but by the Hottentots, the Australians, and the ancient Peruvians and Mexicans. The Negro race seems to be scarcely or not at all inferior in this particular to the Persians, the Bengalees, the Fellahs, the ancient Egyptians, the modern Fellahs, the Chinese, the Polynesians, and the North American Indians. It must be remarked, however, that the number of crania examined is too small, in some of the families, to admit of a fair average. This, however, it is most important to observe, that in the skull of largest capacity amongst the races whose average is the *lowest*, the cubical content is greater than that of the *smallest* skull among the *highest*. Thus we see that the largest native African skull contained 99 cubic inches; the largest American-born Negro, 89 cubic inches; and the largest Hottentot and Alforian skulls, 83 cubic inches; whilst, on the other hand, the smallest German skull contained but 70 cubic inches; the smallest English, 91 inches; and the smallest Anglo-American, 82 cubic inches. It is worthy of note, too, that the largest Negro skull possesses two inches more capa-

TABLE

Showing the Size of the Cranial Cavity in Cubic Inches.

Races and Families.	No. of Skulls.	Largest Skull.	Smallest Skull.	Mean.	Mean.
MODERN CAUCASIAN GROUP.					
Teutonic Family.					
Germans	18	114	70	90	
English	5	105	91	96	92
Anglo-Americans	7	97	82	90	
Pelasgic Family.					
Persians, Armenians, Circassians	10	94	75	84	
Celtic Family.					
Native Irish	6	97	78	87	
Indostanic Family.					
Bengalees, &c.	32	91	67	80	
Semitic Family.					
Arabs	3	98	84	89	
Nilotic Family.					
Fellahs	17	96	66	80	
ANCIENT CAUCASIAN GROUP.					
Pelasgic Family.					
Græco-Egyptians	18	97	74	88	
Nilotic Family.					
Egyptians	55	96	68	80	
MONGOLIAN GROUP.					
Chinese Family	6	91	70	82	
MALAY GROUP.					
Malayan Family	20	97	68	86	85
Polynesian Family	3	84	82	83	
AMERICAN GROUP.					
Toltecan Family.					
Peruvians	155	101	58	75	79
Mexicans	22	92	67	79	
Barbarous Tribes.					
Iroquois, Lenapé, Cherokee, Shoshoné, &c.	161	104	70	84	79
NEGRO GROUP.					
Native African Family	62	99	65	83	83
American-born Negroes	12	89	73	82	
Hottentot Family	3	83	68	75	
Alforian Family.					
Australians	8	83	63	75	

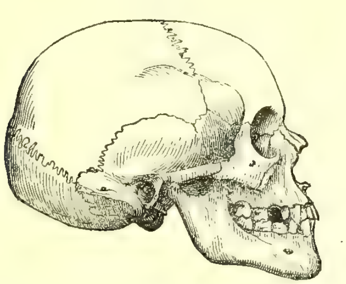
* Transactions of the American Medical Association, vol. iii. p. 57.

city than the largest Anglo-American. It is obvious, then, that no constant and impassable line of distinction can be drawn on this basis, between any of the varieties of the human race.

We have now to inquire if the foregoing types of cranial conformation are sufficiently fixed and definite to furnish *specific* characters; that is (1.), whether they are always clearly distinguishable from each other, or are connected together by a succession of gradations that renders it impossible to draw a distinct line of demarcation between them: and (2.) whether they are so invariably transmitted from one generation to another, where the purity of the race has been preserved, as to entitle them to be regarded as permanent and unalterable; or are occasionally seen to vary in a succession of generations, so that a race loses more or less completely its original type, and assumes some other.

When the cranial conformation of the whole Indo-Atlantic group of nations is carefully examined, it is perceived that although the elliptical type prevails among them, it is comparatively seldom seen in its perfection, and that a decided tendency is frequently seen towards one or other of the other types, or towards a mixture of the characters of all. Considerable variation is thus presented, not merely by the different races, but by different individuals of the same race. Thus in every large collection of English skulls, for example, crania would probably be found differing nearly as widely from each other in the proportion of length to breadth, as do the average of Negro and Mongolian crania; whilst, again, some would exhibit more or less of approximation to the prognathous type, and others to the pyramidal. Of the former we have an example in *fig.* 818., and

Fig. 818.



Dolichocephalic Cranium of European. (From a specimen in the Museum of the Royal College of Surgeons.)

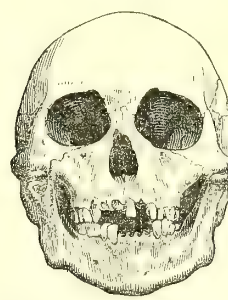
of the latter in *fig.* 819.*; the first of these skulls would certainly be placed, if the dimen-

Fig. 819.

Brachycephalic Cranium of an Englishman. (From a specimen in the Museum of the Royal College of Surgeons.)

sions of its cranial portion were alone regarded, in the "dolichocephalic" division of Professor Retzius, and only wants a little more elongation of the muzzle to be almost as prognathous as many African skulls; whilst in the second, the breadth and front-flattening of the malar bones, with the inferior breadth of the forehead, show that it is obviously intermediate in character between the typical oval (*fig.* 815) and the typical pyramidal (*fig.* 811). So, again, if the so-called Mongolian group be surveyed, it will be found that the peculiarities of the pyramidal skull are often softened down, so as to present an approach to the elliptical form, sometimes through the whole of certain races, occasionally only in individuals. Here, too, there is a tendency to an admixture of types; for we find among the American nations a very gradual transition from the truly pyramidal, such as is seen in the Esquimaux (*fig.* 820),

Fig. 820.



Cranium of Esquimaux. (From a specimen in the Museum of the Royal College of Surgeons.)

to a form in which there is at least as great an admixture of the prognathous (*fig.* 822); whilst among the Chinese and other civilised nations of South-eastern Asia, we find so close an approximation to the oval type, that individuals are not unfrequently met with amongst them, whose skulls might be taken for those of Europeans.* So, again, if we

* Of these and most of the other figures of crania illustrating this article, the author would remark that, although every pains has been taken by the artist, it has been found impossible to express adequately on a small scale some of those nicer features of distinction, which are obvious enough in the skulls themselves.

* Such was the case, for example, with the Chinese skull, whose measurements are given by Professor Van der Hoeven (op. cit.); for in every one of its dimensions it varied less from the aver-

Fig. 821.

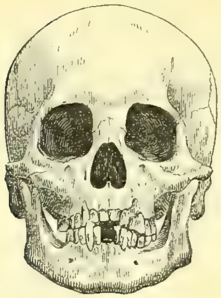


Fig. 822.

Cranium of Masacusi Indian. (*From a specimen in the Museum of the Royal College of Surgeons.*)

take a survey of the African nations, we find the prognathous type gradually softened down (so to speak) among them, until in some of the races of undoubted African descent, inhabiting the Nile valley, it merges into the oval. We have already noticed the curious admixture of the pyramidal and prognathous types which is seen in the Hottentot races; and among the widely spread and isolated tribes by which Oceania is peopled, the same combination is exhibited in various degrees. For whilst the skulls of the Malayan portion of the population are referable to the pyramidal type rather than to any other, those of many native Australians, and of various islanders designated as "Pelagian Negroes," are almost purely prognathous, presenting but a very slight indication of a pyramidal tendency about the upper part of the face; and between these there is every degree of gradation. Thus, in the Australian skull, delineated in *figs.* 823, 824, there is decidedly less prognathism

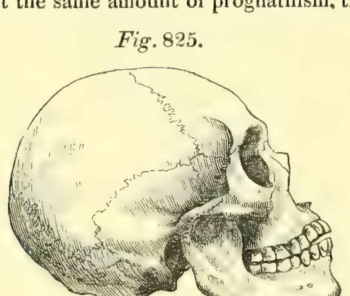
Fig. 823.

Fig. 824.

Cranium of Aboriginal Australian. (*From a specimen in the Museum of the Royal College of Surgeons.*)

than in that already described (*fig.* 808.); and in the skull of the Tahitian (*fig.* 825), with about the same amount of prognathism, there

Fig. 825.



Cranium of a Tahitian. (*From a specimen in the Museum of the Royal College of Surgeons.*)

is a considerably less degree of antero-posterior elongation; in both these skulls, moreover, the upper part of the face, when seen in front, shows a decidedly pyramidal tendency. So, again, the Greenlanders are ranked by Professor Retzius among his *Dolichocephalæ prognathæ*, along with the Negroes and Australians, although the upper part of the face is often most characteristically pyramidal; and even the *Brachycephalic* Tartars and Kalmuks are reckoned by him sufficiently prognathous to be separated from the Finns, Lapps, Turks, &c.

These facts, to which many more might be added, should be sufficient to convince every philosophic naturalist, who duly estimates what is required for the establishment of specific distinctions, that none such can be laid down among the different races of mankind, upon the foundation of cranial conformation alone. Those ethnologists who hold the doctrine of originally distinct stocks, which (they maintain) have continued to preserve their characteristic features through successive generations, have been obliged to admit, not three or five varieties of cranial conform-

age of European skulls, than the latter varied from each other.

ation, but twenty or thirty; and as we increase our acquaintance with the physical characters of tribes at present little known, the number requires continual enlargement. And whether the types selected be few or many, they are always found to be connected by such a gradation of intermediate or transitional forms, that the well-marked boundary-lines which are necessary for the limitation of species, cannot be drawn with the slightest show of justification. It is not meant to be here asserted, that the absence of any such definite peculiarities of cranial conformation is of itself a sufficient reason for regarding the several races of mankind as specifically identical. On the contrary, as we have already seen, the genus *Felis* contains species as unmistakeably distinct as the lion and the tiger, between which there is no appreciable difference in cranial conformation All that we have a right to affirm is (1.), that the most extreme differences in the configuration of the skull, existing among the several races of men, are *not greater* than those which present themselves among races of domesticated mammals *known* to have had a common origin (*e.g.* those of the hog), and are *not nearly so great* as those existing among other races of mammals (as the various breeds of dog,) which are generally *believed* to have had a common origin; and (2.) that, as in the case of the domesticated races, the distinctive characters are by no means clearly marked out, but that those of the *typical forms* are softened down in intermediate gradations, so as to present a continuous series from one type to another, in which no such hiatus is left, as *would justify* the assumption of the specific distinctness of those types. This last fact of itself invalidates that supposition of the uniform transmission of physical characters from parent to offspring, on which the presumption of original distinctness mainly rests. For, on the theory of *specific* distinctness, all the descendants of the same parentage should repeat the characters of their ancestors without essential modification; whereas we find, as a matter of fact, that the distinctive characters are perpetuated in their full intensity in only a small proportion of each race, and that in the great masses they are so shaded off as gradually to disappear. And this must be admitted, whatever types we may select as those representing the original species; unless we go to the extreme length of selecting a distinct type for every distinguishable modification in the conformation of the skull, which would be a sort of *reductio ad absurdum* of the hypothesis.

We are thus led to the second branch of the inquiry, namely, whether there is adequate evidence that the cranial characters of the several races *are* really thus transmitted, with little or no modification, from generation to generation, or whether an actual passage may be effected *in time* from one type to another. Now, every one who has been accustomed to discriminate the varieties of cranial conformation which present themselves within his own range of observation, must have noticed that not only between the parents and their offspring, but also among the different children of the same parentage, a considerable diversity not unfrequently exists. Further, on looking at the various individuals composing the ramifications of a particular family, it is frequently observable that they agree among themselves in some peculiarity of cranial configuration, which seems (from the evidence of portraits, busts, &c.) to have been transmitted downwards for centuries; and by this very character it may be separated from other families, which are in like manner distinguished for their respective peculiarities. Now, there can be no reasonable doubt that many such families had originally a common ancestry, so that there must have been a time when each of these peculiarities *first* manifested itself in its own branch of the common stock; for, if this be not admitted, we must suppose each of them to have descended from a distinct pair of "protoplasts." It is obvious, then, that the question of possible modification is only one of *degree;* and judging by the analogy of the domesticated races, by the amount of variation exhibited under circumstances not *very* dissimilar, and by the considerations already advanced (p. 1303. *et seq.*) respecting the probable sources of such variations, we should be prepared to expect that even the widest diversities which have been described, might have been occasioned by the sufficiently-prolonged influence of external causes acting upon a succession of generations. That such *has been* the case to a considerable extent, would appear in some instances from the direct evidence of history; in other instances it would seem a necessary inference from the facts of philology; whilst in others, again, the two classes of evidentiary facts, neither of them sufficient in themselves, tend to confirm each other.

One of the most striking examples of this kind is afforded by the change in cranial conformation from the pyramidal to the elliptical, as well as in other characters, especially the length and abundance of the beard,—which has taken place among the Turks of Europe and Western Asia. These so closely accord in physical characters with the great bulk of European nations, and depart so widely from the Turks of Central Asia, that many writers have referred the former to the (so-called) Caucasian, rather than to the Mongolian stock. Yet historical and philological evidence sufficiently proves, that the Western Turks originally belonged to the Central Asiatic group of nations; with which the eastern portion of their nation still remains associated, not only in its geographical position, but in its language, physical characters, and habits of life; and that it is in the western branch, not in the eastern, that the change has taken place. Some writers have supposed that this change might be explained as the result of an intermixture of the Turkish race with the inhabitants of the countries they have conquered, or by the introduction of Georgian or Circassian slaves into their harems. But the cause suggested is plainly inadequate to the effect. For we know that in the Christian countries subjugated by the Turks, the conquering and the conquered races have been kept from properly *domestic* intermixture by mutual hatred, fostered by their difference in religion and manners; and although Greek, Georgian, and Circassian females have been introduced into the harems of those who could afford to purchase them, yet any other modification which has been effected by their means must have had but an insignificant effect upon the mass of the population, since the pure Turkish descent of the poorer classes must have been but little interrupted, and universal experience shows that if the "cross-breeding" be not kept up, any new element introduced into a race speedily disappears. Even admitting that *some* modification may have been thus engendered, we cannot fairly attribute to it more than a very trifling share in the result; since the effect of intermixture would simply have been to produce a hybrid or intermediate race, instead of the entire substitution of the elliptical type, which now manifests itself among the comparatively civilised Western Turks, whilst those which inhabit Central Asia, and retain the nomadic habits of their ancestors, have retained also their cranial conformation.

Another instance of the same modification is to be found in the Magyar race, which forms a large part of the population of Hungary, including the entire nobility of that country. This race, which is not inferior in physical or mental characters to any in Europe, is proved by historical and philological evidence to have been a branch of the great Northern Asiatic stock, which was expelled about ten centuries since from the country it then inhabited (which bordered on the Uralian mountains), and, in its turn, expelled the Slavonian nations from the fertile parts of Hungary, which it has occupied ever since. Having thus exchanged their abode, from the most rigorous climate of the old Continent, — a wilderness in which Ostiaks and Samoiedes pursue the chase during only the mildest season, — for one in the South of Europe, amid fertile plains abounding in rich harvests, the Magyars gradually laid aside the rude and savage habits which they are recorded to have brought with them, and adopted a more settled mode of life. In the course of a thousand years, their type of cranial conformation has been changed from the pyramidal to the elliptical; and they have become a handsome people, with fine stature and regular European features, with just enough of the Tartar cast of countenance, in some instances, to recal their origin to mind. Here, again, it may be said that the intermixture of the conquering with the conquered race has had a great share in bringing about this change; but a similar reply must be returned; for the existing Magyars pride themselves greatly on the purity of their descent; and the small infusion of Slavonic blood, which may have taken place from time to time, is by no means sufficient to account for the complete change of type which now manifests itself. The women of pure Magyar race are said by good judges to be singularly beautiful, far surpassing either German or Slavonian females.

A similar modification, but less in degree, appears to have taken place among the Finnish tribes of Scandinavia. These may be almost certainly affirmed to have had the same origin with the Lapps*; but whilst the latter retain (although inhabiting Europe) the nomadic habits of their Mongolian ancestors, the former have adopted a much more settled mode of life, and have made considerable advances in civilisation, especially in Esthonia, where they assimilate with their Russian neighbours. And thus we have in the Lapps, Finns, and Magyars, three nations or tribes, of whose descent from a common stock no reasonable doubt can be entertained, and which yet exhibit the most marked differences in cranial characters, and also in general conformation, the Magyars being as tall and well-made, as the Lapps are short and uncouth.

Another instance of the same kind, which is still more remarkable if it can be entirely substantiated, is the conversion of the Georgian and Caucasian nations from the pyramidal or Mongolian to the elliptical or Indo-European type. The designation *Caucasian* seems to have been given to the latter on the following most unsatisfactory ground. "Blumenbach had a solitary Georgian skull; and that solitary skull was the finest in his collection, that of a Greek being next. Hence it was taken as the type of the skull of the more organised divisions of the species. More than this, it gave its name to the type, and introduced the term Caucasian."† Now the fact is, that the Georgian and Circassian

* This proposition, which is supported by the almost unanimous voice of the learned historians of Germany, was assailed a few years since by Profs. Nilson, Retzius, and other Scandinavian savans, who endeavoured to prove by archæological and anatomical evidence, that the origin of the Finnish race was not the same with that of the Lapps, but that it was more nearly connected with the Swedish nation, which is a northern branch of the great Indo-European family. Much of the archæological evidence adduced, however, is capable of receiving a directly opposite interpretation; and the philological evidence, derived from the comparative study of the Finnish and Swedish languages, shows that the basis of the former was essentially peculiar to it, and that the nature of the modification which it has undergone from Swedish influence, indicates a considerable advance in civilisation previously to the subjugation of the race by foreign invaders. Dr. Latham, the latest authority on this subject, expresses himself very decidedly as to the affinity of the Finns, Lapps, and Hungarians, whom he ranks with the Voguls, Ostiaks, and Permians, as off-sets of the Ugrian branch of the Turanian (Mongolian) stock.—See his Natural History of the Varieties of Man, p. 100.

† Latham, op. cit. p. 108.

nations are composed of an assemblage of tribes inhabiting a mountainous country, speaking languages almost unintelligible to each other, and remarkably isolated from the nations which inhabit the countries bordering on theirs. The beauty of form and feature, and the delicacy of complexion, which characterise individuals and families among these

Fig. 826.

Portrait of a young Circassian, belonging to the suite of the Persian Ambassador. (*From a portrait taken in Paris by M. A. Colin.*)

tribes, are well known (*fig.* 826.) and have led to a regular consignment of the youth of both sexes to the Turkish market, the females to be introduced into the harems, whilst the youths are valued for their superior energy and intelligence, and are frequently adopted as sons. But these attributes are for the most part confined to the families of the chiefs; and they are carefully cherished by exemption from labour, and by seclusion from undue exposure. The common people, who are engaged in the cultivation of the soil, are described by travellers as being for the most part coarse and unshapely.—Now from a careful comparison and analysis of the languages of these races, Dr. Latham and Mr. Norris have independently arrived, on different grounds (the one from the *words* and the other from the *grammar*), at the same result; namely, that they are *aptotic*, or destitute of inflexions, like the Chinese; and that the people must have been of *Mongolian* origin, but separated from the common stock at a very early period; the perpetuation of the low development of their language being favoured by the peculiar characters of the country in which they located themselves, whilst these same characters tended to modify their physical conformation. For the area which they occupy is at once temperate, mountainous, and wooded; "in other words," as Dr. Latham remarks, "the reverse of the true Mongol areas." And thus, if this view should be confirmed, we must regard the very people which has been selected as furnishing the type of the most perfect conformation, as an improved race of a decidedly inferior stock.

The Negro type is one which is not unfrequently cited as an example of the permanence of the physical characters of races, and especially of types of cranial conformation. The existing Ethiopian physiognomy is said to agree with the representations transmitted to us from the remotest times in Egyptian pictures; and this physiognomy, it is further maintained, continues to be transmitted unchanged from parent to child, even where the transportation of a Negro population to temperate climates and civilised associates (as in the United States of America) has entirely changed the external conditions of their existence. Now it is perfectly true that the Negro races which continue to inhabit their original localities, and maintain their barbarous habits of life, retain the prognathous type; and this is precisely what we should expect. But it is *not* true that no modification has taken place in them, either under the influence of civilisation, or from a change in the physical conditions of their existence. For the most elevated forms of skull occurring among the African nations, are found in those which have emerged in a greater or less degree from their original barbarism; their civilisation having been due to external influences brought to bear upon them. We shall hereafter see that there is strong evidence that even the Syro-Arabian or Semitic nations may be referred to the African stock; at any rate, there are numerous tribes in the interior of Africa, whose affinity with the true Negroes cannot be disputed, and which yet present a far superior cranial organisation; so that we must either regard the one form to be the result of improvement, or the other to have preceded from degeneration. In regard to the transplanted Negroes, it is obvious that the time which has elapsed since their removal, is as yet too short to justify us in expecting any considerable alteration in cranial configuration. Many of the Negroes now living in the West Indian islands are natives of Africa; and a large proportion of the Negro population, both there and in the United States, are removed by no more than one or two descents from their African progenitors. The climate, too, of the southern states of the North American Union, as of the West Indies, is not very different from that of the Guinea Coast, in regard to temperature; and the low undrained character of much of the soil which they are employed in cultivating, still further tends to keep up the correspondence. Still, according to the concurrent testimony of disinterested observers, both in the West Indies and in the United States, an approximation in the Negro physiognomy to the European model *is* progressively taking place, in instances in which, although there has been no intermixture of European blood, the influence of a higher civilisation has been powerfully exercised for a lengthened period. This is particularly the case with Negroes employed as domestic servants. Dr. Hancock, a most intelligent physician of Guiana, even asserts that it is frequently not at all difficult to distinguish a Negro of pure blood, belonging to the Dutch portion of the colony, from another belonging to the English settlements, by the correspondence between the features and expression of each, and those which are characteristic of their respective masters. This alteration, too, is not confined to a change of form in the skull, or to a diminution in the projection of the jaw; but it is also seen in the general figure, and in the form of the soft parts, as the lips and nose. And the writer has been informed by Sir Charles Lyell, that during his recent tour in America, he was assured by numerous medical men residing in the slave states of the North American Union, that a gradual approximation is taking place in the configuration of the head and body of the Negroes to the European model, each successive generation exhibiting an improvement in these respects. The change is most apparent in such as are brought into closest and most habitual relation with the whites (as by domestic servitude), without any actual intermixture of races, which would be at once betrayed by the change of complexion, and by the more strongly marked indications of hybridism.

It is more easy to imagine that a pyramidal or a prognathous cranium can be metamorphosed into an elliptical one, than that either of the two first-named forms can be converted into the other. Yet very strong evidence is furnished by philological considerations, that the Hottentot races constitute a branch of the common African stock; and the approximation which their skulls present to the pyramidal type cannot be for a moment attributed to intermixture with any Mongolian race. On the other hand, among the inhabitants of Oceania, there are many races which present, more or less decidedly, the prognathous type; and this sometimes associated with woolly or "frizzled," sometimes with long and straight hair. Yet there is strong philological evidence for regarding these as descendants of colonists who spread themselves (probably by various lines of migration) from south-eastern Asia, and who carried to the various islands of the vast Malayo-Polynesian Archipelago, the pyramidal type more or less softened down. On no other hypothesis can the extraordinary community in the fundamental elements of their languages be accounted for, the tribes which use them being in a state of complete isolation from each other. Where, as is frequently the case, the same island or group is peopled by two or more races, having different physical characters, it is always found that the greatest tendency to the prognathous type shows itself among those which appear to have longest dwelt there in a state of barbarism; and that it is most strongly marked, when, to other degrading agencies, that of a low and marshy soil has been added.

Even the elliptical type, as already remarked, may occasionally present indications of degradation towards one of the others. Want, squalor, and ignorance, have a special tendency to induce that diminution of the cranial portion of the skull, and that increase of the facial, which characterise the prognathous type; as cannot but be observed by any one who takes an accurate and candid survey of the condition of the most degraded part of the population of the great towns of this country, but as is seen to be pre-eminently the case with regard to the lowest classes of Irish immigrants. A certain degree of regression to the pyramidal type is also to be noticed among the "nomadic" tribes which are to be found in every civilised community. Among these, as has been remarked by a very acute observer, "according as they partake more or less of the purely vagabond nature, doing nothing whatsoever for their living, but moving from place to place, preying on the earnings of the more industrious portion of the community, so will the attributes of the nomade races be found more or less marked in them; and they are all more or less distinguished for their *high cheek bones and protruding jaws;*" * thus showing that kind of mixture of the pyramidal with the prognathous type, which is to be seen among the most degraded of the Malayo-Polynesian races.

It has not been pointed out, so far as the writer is aware, by any ethnologist, that the conformation of the cranium seems to have undergone a certain amount of alteration even in the Anglo-Saxon race of the United States, which assimilates it in some degree to that of the aboriginal inhabitants. Certain it is, that, among New Englanders more particularly, a cast of countenance prevails, which usually renders it easy for any one familiar with it to point out an individual of that country in the midst of an assemblage of Englishmen; and although this may chiefly depend upon the conformation of the soft parts, yet there is a certain sharpness, and an angularity of feature about a genuine "Yankee," which would probably display itself in the contour of the bones. So far as the writer's observation has extended, there is especially to be noticed an excess of breadth between the rami of the lower jaw, giving to the lower part of the face a peculiar squareness (something like that which is shown in *fig.* 821), that is in striking contrast with the tendency to an oval

* London Labour and the London Poor; by Henry Mayhew, p. 2.

narrowing which is most common among the inhabitants of the "old country." And it is not a little significant, that the well-marked change which has thus shown itself in the course of a very few generations, should tend to assimilate the Anglo-American race to the aborigines of the country; the peculiar physiognomy here adverted to, most assuredly presenting a transition, however slight, towards that of the North-American Indian.

2. *Conformation of the Pelvis.* — Certain differences in the pelvis have been thought to be characteristic of particular nations or groups of nations. According to Professor Vrolik*, who was the first to take up the enquiry systematically, the difference between the male and the female pelvis is much more strongly marked in the Negro than in the European. The pelvis of the male Negro, in the strength and density of its substance, and in the form of its component bones, resembles the pelvis of a wild beast; while, on the contrary, the pelvis of the female of the same race combines lightness of substance and delicacy of form and structure. Notwithstanding this delicacy of conformation, it is considered by Professor Vrolik to present characters which indicate an approximation to that of the Quadrumana; for the ossa ilii are unusually vertical in their direction, and the highest part of their crest is situated immediately above the posterior and upper tuberosity, instead of being midway between the anterior spine and posterior tuberosity; the length of the antero-posterior diameter at the brim is very great in proportion to the transverse diameter; the sacrum is narrower, and the angle beneath the pubic articulation more acute; the whole pelvis is longer; but the diameters at the outlet are not sensibly different from those of the European pelvis. The conformation of the pelvis in the female Hottentot, who died in Paris in 1815, is considered by Professor Vrolik to present a still wider departure from the European form, and a correspondingly nearer approximation to the quadrumanous; the ilia are so vertical in their direction, and are so much lengthened upwards, as to rise above the level of the middle of the fourth lumbar vertebra. In the Javanese (Malay), the pelvis is distinguished by its smallness, its peculiar lightness of substance, and the circular form of its upper aperture; the promontory of the sacrum projects very little; and the ischiadic spines are remarkably turned inwards.

A more extended comparison of the pelvis of different races, however, has been made by Professor M. I. Weber; who classifies all the varieties he has met with under the four following heads, which are named according to the form of the aperture of the brim: —

1. The *oval*, in which the aperture has somewhat the form of an egg, the narrowest end of the ellipse being at the symphysis pubis: but the antero-posterior diameter is shorter than the transverse.

2. The *round*, in which the antero-posterior and transverse diameters are nearly equal.

3. The *square*, or four-sided; in which the sides, especially that formed by the os pubis, are flat and broad, so that the aperture forms nearly a perfect square; the transverse diameter is greater than the antero-posterior.

4. The *oblong*; in which the sides are compressed, and the transverse diameter is consequently the least; the sacrum is narrow; and the angle at which the ossa pubis unite is very acute; the ossa ilii are high, and nearer to each other than in the previous forms.

Now, if any attempt be made to assign any one of these forms of pelvis to a particular nation or group of nations, it fails *in toto;* because, although particular types are more common than others in each principal variety, yet each kind may present itself in other individuals of the same race. Thus, the *oval* type is most common in the European, where it is in accordance with the oval form of the skull; but round, square, and wedge-shaped pelves also present themselves occasionally; and the oval form is met with again in the pelvis of a Botacudo, a people reputed to be the most savage of all the American nations. The *round* type seems most frequent among the American and Malayan nations; but it has been observed by Weber not merely in the European, but in a Negress, and in a female Hottentot. The *square* form seems most common among the nations with decidedly pyramidal skulls, especially the Northern Asiatics; but it occurs also in Europeans, and in the mixed race of Mestizos. Finally, the *oblong* pelvis is most common among the African races, and is conformable to the elongated shape usually possessed by their crania; but it has been observed also among Europeans and Botocudos.* — The writer's own observations, so far as they extend, confirm this view, as to the conformity between the shape of the pelvis and that of the skull; which renders it probable that the influences which affect the latter will modify the former also.

3. *Conformation of other parts of the skeleton.* — Other characters have been at different times adduced, as showing that the Negro and other degraded races are really to be considered as forming a distinct group, intermediate between the higher specimens of humanity and the superior apes. Of these, the most important will be now inquired into. It was maintained by Soemmering, and since his time very generally believed, that the position of the foramen magnum in the Negro skull is intermediate between that which it holds in man, and that which it presents in the anthropoid Simiæ; but this, as already shown, is a mistaken view of the case; for,

* Platen behoorende tot de Beschowing van het Verschel der Bekkens in onderscheidene Volkstammen. Amsterdam: 1826.

* Die Lehre von den Ur- und Racenformen der Schaedel und Becken des Menschen, von Dr. M. I. Weber. Düsseldorf: 1830.

if we make allowance for the projection of the jaws, and consider only its relation to the cranial portion of the skull, the position of the foramen magnum is found to be the same in the Negro as in the European; whilst in the adult forms of the highest apes, as shown by Professor Owen, it is removed very much further back, although in the young it is nearer the centre of the base. Again, it was stated by White, and has been generally believed, that the length of the fore arm in the Negro is so much greater than in the European, as to constitute a real approximation to the quadrumanous type. But an extended comparison proves, that only a very slight difference exists between the *average* length of this part in the two races; and that this difference is by no means greater than that which may be observed on comparing the individuals of which any single race or nation is composed. On the other hand, a constant and decided difference exists, as already pointed out, between all races of mankind and the highest Quadrumana. Again, it has been supposed that the Negro races are characterised by that peculiar curved form of the bones of the leg, which gives rise to what is popularly designated as the "cucumber-shin;" also by the great elongation of the heel; and by the breadth and flatness of the foot. Such peculiarities are doubtless to be observed among individuals, and may be said to be general among the inferior Negro tribes; but they are scarcely discoverable in the higher, among which a remarkable degree of symmetry in the conformation of these parts is often discernible. And it should not be forgotten that the increased development of the heel, and the flattening of the foot, are characters which *remove* the Negro from the anthropoid apes, still more widely than the European, instead of being a character of approximation. It has been further asserted, that the inferior races generally are characterised by slender, elongated, and mis-shapen limbs, and by a great deficiency of physical power, as compared with Europeans. This is undoubtedly true of such as are habitually ill-fed, and live in a condition of squalid ignorance. But it is scarcely less true of those individuals among any of the higher races, who are subjected to the same conditions. Thus, although the extreme of this condition is witnessed among the Bosjesmans and Alfourous, yet approaches to it may be seen among the lowest grades of the population in the most civilised nations. The accompanying figure (*fig.* 827), which represents a group of Australians looking at a mirror that had been presented to one of their tribe, who had been clothed by the sailors of the *Astrolabe*, might almost be supposed to be intended for a set of half-starved Irish. Moreover, among the races which are considered to exhibit this character in its most decided form, individuals are often found, who, having grown up under more favourable conditions, exhibit the most complete symmetry, and the greatest vigour. Such, for example, are not wanting among the Australian races, which present a remarkable variety in this particular. Among most savage races, the families of the chiefs exhibit a higher grade of physical development than the ordinary population; and this is quite sufficiently accounted for by the

Fig. 827.

difference of the conditions under which they live, especially in regard to food.

It may be safely asserted, then, that on none of the foregoing characters can specific distinctions be justly based, since none of them possess the constancy which is required to give them such a rank; and those which are most strongly marked in particular cases, are such as can be proved to be most liable to modification from external conditions.

4. We next have to inquire into the distinctions founded upon the *Colour of the Skin;* which, at first sight, appear to present a degree of constancy that gives them a strong claim to be regarded as permanent, and therefore as valid distinctive characters between the several races of mankind. The hue of the Skin, it is now well known, exists in the epidermis only, and depends upon the presence of pigmentary matter in the ordinary cells of that part. What was formerly known as the "rete mucosum," or "rete Malpighii," and described as a distinct colouring layer between the epidermis and cutis vera, is now known to be nothing else than the newest and softest layer of epidermis. There is no structure (as has been affirmed by some anatomists) in the skin of the dark races, that is at all peculiar to it; the very same dark matter being found in particular spots of the fairest skins, as in that of the areola surrounding the nipple during pregnancy. The following is the description of the structure given by Messrs. Todd and Bowman, the accuracy of which the author can fully confirm from his own observation:—"However various in colour and hue, the colouring matter always consists of oblong or oval grains of extreme minuteness (1-20,000th of an inch in their long diameter), and occupying the interior of some of the epidermic particles. In the Negro it is accumulated in enormous quantity, and completely envelopes the nuclei immediately resting on the cutis. On examining a vertical section of the whole cuticle, we find the colouring matter gradually diminishing as we approach the surface; and it is most clear that there is no true line of demarcation between the two portions. We may observe the colour of the rete mucosum deeper at points; and a greater proportionate depth of colour is traceable over such points, through all the layers, as far as the surface; we may even discern a sort of stream of coloured grains advancing towards the surface. Hence there can be little doubt that the decrease of colour in the superficial laminæ is due to that chemical change which has been described as gradually taking place in the interior of the epidermic particles."*

Still it might be affirmed that the presence of a large amount of pigmentary matter, of a peculiar tint, in the substance of the epidermis, constitutes a typical character of particular races, even though there be no distinct pigmentary layer; since spots and patches of colour are often admitted as specific distinctions among the lower animals. Thus, for example, it has been maintained that the fair and ruddy Saxon, the jet-black Negro, the olive Mongolian, and the copper-coloured North-American, have as good a claim to be ranked as distinct species, on the score of the uniform transmission of their respective hues from generation to generation, as have many races of Lepidoptera (for example) which are regarded by naturalists as specifically diverse on account of the distribution of colour in the scales of their wings. But as the validity of the specific distinction among these last entirely rests upon the *intransitive* nature of the character, the several individuals that constitute either race exhibiting no approximation towards those of the other, and the successive generations repeating the respective peculiarities of each race with great exactness, we must apply the same test to the Human races.

Now, if we take any one of those groups of nations which are usually regarded as altogether constituting a *race*, such as the (so-called) Caucasian, the Mongolian, the African the American, or the Polynesian, it will be found that the greatest diversity of complexion exists within its limits. Thus, among the "*Japetic*" races,—which are characterised by the possession of the oval type of cranial conformation, and whose languages are so clearly traceable to a common stock, that no philologist now questions the identity of their origin,—we find every range of colour, from the fair Saxon and Celtic nations, to the deep brown of the Indian Brahmin.* Among the Syro-Arabian, or "*Semitic*" races, again, which are spread over South-western Asia and Northern Africa, and which are connected by close affinity of language, there is an equal variety of complexion. All travellers who have visited the high lands of Arabia, represent the inhabitants as having light complexions, their eyes being often blue, and their hair red. The Arabs near Muscat are of a sickly yellow hue; those of the neighbourhood of Mecca are of a yellowish brown, while those of the low countries bordering on the Nile are almost jet-black. So, again, among the various tribes referable to the same stock, which inhabit the Atlantic region of the north of Africa, similar differences of complexion prevail; for whilst those which inhabit the higher lands and mountain passes, such as the tribe of Mozabi among the Kabyles, are remarkably fair, those which dwell in the more level parts of the country are swarthy,

* Physiological Anatomy, vol. i. p. 415.—The Rete Malpighii is represented by Prof. Kölliker as more distinct from the superjacent layers; but the writer has not been able to satisfy himself of the accuracy of the descriptions and figures of Prof. Kölliker on this point. See his Microskopische Anatomie; Zweiter Band, §§ 14—22.

* The hue of many of the races of Lower India is as black as that of any Negroes; but there is a doubt (as will hereafter appear) as to their origin. If not Indo-Atlantic, however, they are Mongolian; and the peculiarity is at least as striking, when they are viewed as off-sets from the latter stock, as when they are considered as appertaining to the former.

and some of the Tuaryks which inhabit the borders of the Great Desert, are as black as the darkest Negro.

Among the proper *African* nations, it may be supposed that no such variety would embarrass us; blackness, with a reddish or yellowish tinge, being accounted the universal hue of the Ethiopian race. But this notion is chiefly founded upon the complexion which prevails in a very small part of the great African continent; and no fact is really better established, than that of the great diversity of complexion which prevails among its different inhabitants. Thus, among some of the Kaffir tribes,—which often possess high foreheads and prominent noses,—light brown complexions, and reddish hair are often met with; yet there is every reason for the belief that they are of the same stock with the Negroes of the Guinea coast, and intermediate gradations in complexion are presented by the nations which occupy an intermediate geographical position. There are tribes even upon the gold and slave coasts, which are considerably lighter than ordinary Negroes. Moreover, the Hottentot has a large admixture of yellow in his complexion, whilst the Fúlahs of Central Africa are of a dark copper colour. The African tribes which border on the Red Sea, and which seem to constitute the link of transition between the Ethiopian and the Semitic races, present every grade of colour, from the deep black of the Negro to the swarthiness of the lighter Arabs, notwithstanding that there is no reason to believe these characters to have been acquired by the intermixture either of an Ethiopian stock with Arabs, or of an Arab stock with Ethiopians. There is strong ground for the opinion, as we shall see hereafter, that the ancient Egyptians, whose complexion (as represented by their own artists) seems to have been of a red copper or light chocolate colour, were so closely allied to the proper African nations, that the origin of both must have been the same.—The complexion of the African nations, then, wants that character of uniformity, which is required to distinguish it from that of other branches of the human family; and a marked tendency to assimilation is exhibited in the hues of the African and of the Semitic races inhabiting similar localities, a fact whose full significance will appear hereafter.

On instituting a similar comparison between the complexions of the various branches and off-sets of the *Mongolian* race, it will appear that, although an admixture of yellow is one of its most constant characters, yet this may co-exist with other shades, and may even disappear altogether. Thus, in the remains of the aboriginal tribes of India still existing in the hilly regions of the north, in the Dekhan, and especially in Ceylon, all of which appear, from the characters of their language, their peculiar customs, and their traditions, to be descendants of the Mongolian rather than of the Japetic stock, we find a variety of shades of complexion, and this within the limits of the same people. For example, the Cinghalese are described by Dr. Davy as varying in colour from light brown to black; the prevalent hue of their hair and eyes is black, but hazel eyes and brown hair are not very uncommon; grey eyes and red hair are occasionally, though rarely, seen, and sometimes the light blue or red eye, and light flaxen hair of the Albino. Dr. Davy, in describing such a one, remarks that her complexion would scarcely be considered peculiar in England, certainly not in Norway; for her eyes were light blue, and not particularly weak, her hair of the colour that usually accompanies such eyes, and her complexion rather rosy. This tendency towards a fair and even florid complexion, with light eyes and bushy hair, can be traced in several other nations of the same type, such as the Mantchoos in China, and also among the Chinese themselves. On the other hand, the hardy Samoiedes, Tungusians, Kamschatdales, and others, living on the borders of the Icy Sea, have a dirty brown or swarthy complexion.

If we pass on to the *Oceanic* races, we find that any attempts to employ complexion as a means of distinguishing them from other primary stocks, must utterly fail, so great and numerous are the diversities. In almost every group of islands in the great Oceanic area, the natives differ in complexion from those of other groups; thus the Malays of the Eastern Archipelago, who resemble the Chinese in features and general conformation, are of a darker colour, retaining, however, a yellow tinge in their complexion; this tinge comes out very strongly in the natives of the Caroline Islands, whose aspect is decidedly Mongolian, and whose complexion is of a citron hue, becoming brown by exposure; the Tahitians and Marquesans, especially in the families of their chiefs, which are secluded from the wind and the sun, exhibit a clear olive or brunette complexion, such as is common among the nations of Southern Europe; the Hawaii, or Sandwich Islanders, are somewhat darker; while of the new Zealanders and Ombai Islanders, some are comparatively fair, while others are dark or almost black. Besides these, however, Australia, New Guinea, and some of the neighbouring islands are more or less exclusively peopled by tribes bearing a close resemblance in complexion and aspect to Negroes, whose precise relation to the Malayo-Polynesian races it is difficult to determine. There is, however, such a complete transition from one type to the other, presented by the natives of different localities among whom there is no reason to suppose that any intermixture has taken place, and the differences are such between the higher and lower castes of even the same tribe, that all intelligent persons who have long resided among the islands of the Pacific, under circumstances favourable to accurate investigation, appear to have come to the conclusion,—that none of those characters on which some observers have relied, as being strongly marked in the individuals whom they have happened to see in the course of their brief visits to different localities, can be relied on as general expressions of the attributes of particular races. So that if colour be once adopted as a test of separate origin, we must suppose that tribes speaking the same language, having the same customs and traditions, and closely allied in general conformation, sprang nevertheless from ancestors who had no relation to one another; and a distinct pair must be assigned to almost every island or group of islands, and, in some instances, even two or more pairs to a single island.

Lastly, in regard to the American nations, it is sufficient to remark, that the appellation "red men," is by no means characteristic of them as a whole; for not only are tribes elsewhere found at least equally deserving of it, but it is not applicable to a large proportion of the population of the New Continent. For although some of the North-American Indians are copper-coloured, some are as fair as many Europeans; others are of a brown or yellow complexion; and others nearly, if not quite, as black as African Negroes. Similar diversities exist among the aborigines of South America. Here, also, therefore, we should be forced into the supposition of a large number of primitive stocks in near vicinity to each other, were so much authority to be attributed to colour, as to allow it to rank as a sufficiently distinctive character for the specific discrimination of any of the races of mankind.

We have now to examine if the peculiarities of colour seen among different races can be attributed with any considerable degree of probability to external agencies; and the evidence bearing on this question may be considered under two heads, namely (1.) the constancy of the relation between the habitual operation of particular climatic influences and particular shades of complexion; and (2.) the historical evidence of an actual change of complexion, in races or tribes that are known to have migrated from one locality to another of a different character, or to have changed their mode of life.

Now, the general relation between climate and complexion is apparent on the most cursory survey of the facts. It is only in the intertropical regions, and in the countries bordering on them, that we meet with the greatest depth of colour in the skin; and all the nations inhabiting the level parts of those regions exhibit a tendency towards a very dark hue. On the other hand, the colder temperate regions are the residence of the fair races. And the intermediate countries exhibit the transition from one complexion to the other, as we see on passing from Central Africa, through Northern Africa and Southern Europe, to Northern Europe. Now this, if we had no evidence to the contrary, might fairly be held to indicate that each race had been created with especial reference to a particular climate; the principal difficulty in the way of such a supposition, being the great number of different races whose separate origins it would be necessary to assume, if it be held that each has uniformly exhibited the complexion which it now possesses. But it is most remarkable that elevation above the sea-level is found to have the same uniform relation to the human complexion, that it has to vegetation. For as we find the plants of temperate or even arctic regions on the sides of intertropical mountains, so do we notice that high mountains and table-lands of great elevation are almost uniformly inhabited by people of lighter hue than those of the surrounding country, however close may be their affinity; whilst low and level countries, especially those which border on the sea, are as commonly tenanted by people of an unusually dark colour. Thus the deepest hue among the African races is to be found among the negroes of the swampy plains of the Guinea coast; yet there are several instances, in which nations residing at no great distance from these, but at a higher level, are comparatively light, although their ancestry is undoubtedly the same. In Northern India, again, the lightness of complexion among the inhabitants of the mountains and table-lands is almost exactly in accordance with the elevation at which the tribe has been accustomed to dwell; and some of these present complexions of almost European fairness. On the other hand, among the tribes that wander along the shores of the Icy Sea, their proximity to the ocean, together with their habitual exposure, seem to compensate in some degree for their distance from the equator; so that their hue is much swarthier than that of the more civilised inhabitants of Northern Europe. The influence of seclusion from exposure, in lightening the hue of the skin among the higher castes of various tropical races, has been already remarked upon; and another indication of the importance of this influence is derived from the concurrent though independent observations of M. D'Orbigny and Sir R. Schomburgh upon the people of the New World, both having remarked that those tribes which live under the damp shade of dense and lofty forests, are much fairer than those which are freely exposed to solar light and heat in dry and open spaces. The influence of continued exposure to the solar rays is often strongly marked in individuals of the lighter races; those who are naturally of a "brunette" complexion becoming swarthy, whilst in those who are naturally fair or "blonde," there is a tendency either to a general reddening or "tanning" of the skin, or to the development of "freckles," which are nothing else than local collections of pigmentary matter, usually of a reddish-yellow colour. In such cases, the parts of the body which are habitually kept covered retain their original fairness.

Seeing, then, that continued exposure to the solar rays has such a marked effect upon the complexion of individuals who are subjected to it, we should be led to expect, upon the principles already laid down, that this effect would be increased when the cause is in continued operation for several generations. And we might with the more confidence anticipate such a result, when we see that a marked difference in complexion often exists between parent and offspring, or between the children of the same parents. Thus, it is a matter of familiar observation, that of two members of the same family, the one shall be a *blonde*, the other a *brunette*. Further, it is not uncommon to find, in individuals of the fair races, large patches of the surface almost as deeply coloured as the skin of the negro. On the other hand, *albinoism*, that is, the total absence of colouring matter in the skin, is probably as common among dark races as among fair. And Dr. Prichard has collected evidence which shows that in many of the individuals who have been designated as " white Negroes," there has not been mere albinoism (that is, an entire absence of colouring matter), but a positive development of the colouring matter that characterises the *xanthous* variety, in which the complexion is fair and ruddy. Such being the tendency to variation presented by this character, we might fairly anticipate that it might undergo marked changes in the course of a long succession of generations, especially where the external conditions have been altered; and there is no deficiency of valid historical evidence, that proves this to have been the case.—Perhaps the most striking example that could be cited, is that afforded by the Jewish race; in which there is no question that a general purity of descent has been preserved through a long succession of generations, during which the scattered residence of the race has subjected it to a great variety of climatic influences. Now, although the descendants of Abraham are still generally recognizable by certain peculiarities of physiognomy (so that they have often been quoted as examples of the permanence and fixity of the characters of races), yet a great variety of complexion exists among them. Thus, among the Jews whose families have been long settled in this country, although a light brunette hue with black hair is most common, yet a fair complexion, with blue eyes, is not unfrequent. In Germany and Poland, the ordinary complexion is more florid, and blue eyes are more common. On the other hand, the Jews of Portugal are almost invariably much darker than those of Northern and Central Europe, as are also those who still cling to their ancient home in Palestine. Lastly, the Jews that have been settled in India for a long succession of generations, have become nearly as black as the natives around them, so that the people of a particular colony at Mattacheri, in Cochin, in whom this change has not yet taken place, are distinguished by the appellation of " white Jews." Hence it may be stated as a general proposition, that the complexion of the Jewish race tends to assimilate itself to that prevailing in any country in which their residence has been sufficiently prolonged; and even admitting that a limited admixture with the surrounding population has taken place in any or all of these instances, still the introduction of a small quantity of extraneous blood does not by any means afford an adequate explanation of the change, since it has not been sufficient to alter any of the other characters of the race, and (as already remarked) the immediate results of such an occasional admixture are soon merged in the general uniformity of the mass. It is probable that, in races as in individuals, the influence of a tropical climate in darkening the complexion will be more decided, in proportion to the previous condition of the chromatogenous function; for example, that the Jews, whose natural complexion is swarthy, are more readily blackened than Saxons or Celts would be, the pigmentary matter in their epidermis being of a different character.

There are several other cases of the same kind, in which the historical testimony is less complete, but in which the deficiency is made up by philological evidence. Thus, the Barábra or Berberines of the higher parts of the Nile, appear, from the most careful researches that have been made into their history, to be the descendants of the Nobatæ, who were brought by Diocletian from an oasis in the western country, fifteen centuries ago, to inhabit the valley of the Nile. The particular district out of which they issued was probably Kordofan, the inhabitants of which, true Negroes, still preserve and speak the Barábra language. In their habits of life, they show a considerable advance in civilisation; and this has been accompanied by a considerable change in complexion, their present physiognomy and hue of skin presenting a marked resemblance to that of the ancient Egyptians. This alteration cannot be set down to any intermixture with the Arabs, or other inhabitants of the Nile Valley, from whom the Berberines keep themselves distinct.—In like manner, the Funge, who made themselves masters of Sennaar about three centuries ago, although originally Negroes of the Shilúkh nation, no longer present the physiognomy or complexion of that race, but much more nearly approach the Berberines. There appears, in both cases, to be a special tendency towards a red complexion, and even red hair; and among the Funge, the individuals thus distinguished are stated to form a separate caste, being known under the name of " El Akmar," or "the red people." In Northern India, again, there is no doubt that many of the tribes of mountaineers, already alluded to as distinguished by fair complexion and blue eyes, are of the same stock with the inhabitants of the low country; their language, traditions, religious observances, &c., being essentially the same. One of the most remarkable of these tribes is the Siah-Pôsh, a people of exquisite beauty, with regular Grecian features, blue eyes, arched eyebrows, and a fair complexion, having no resemblance to the Affghan or Cashmerian people, near whom they dwell; their language principally consists of Sanscrit words, although Sanscrit is no longer the spoken language of any part of India; and they are acquainted with only the simplest form of Hindoo mythology; whence it may be fairly concluded, that they separated from the common stock at a very early period.

Thus, then, we have very strong evidence that a certain relation exists between climate and colour; and it is no valid objection to the existence of such a relation, to say that it is not perfectly uniform. For it is at least as uniform as the relation between colour and race, even where the climatic influences are the same; that is, the difference of shade among people of different races that have been exposed sufficiently long to the same climatic influences, is not greater than that which presents itself among individuals of the very same nation. It would seem that, among the most dark-skinned races, there is a greater variety of complexion than is found in those of fairer hue. Such has been already shown to be the case among the Polynesian islanders; and the following extract from Bishop Heber's Journal will serve to indicate the amount of variety existing among the Hindoos. "On first landing," he remarks, "the great difference in colour between different natives struck me much. Of the crowd by whom we were surrounded, some were as black as Negroes, others merely copper-coloured, and others little darker than the Tunisines whom I have seen in Liverpool. Mr. Mill, the principal of the British College, who came down to meet me, and who has seen more of India than most men, tells me that he cannot account for this difference, which is general throughout the country, and every where striking. It is not merely the difference of exposure, since this variety is visible in the fishermen, who are naked all alike. Nor does it depend on caste, since very high-caste Brahmins are sometimes black, while Pariahs are comparatively fair. It seems, therefore, to be an accidental difference, like that of light and dark complexions in Europe; though, where so much of the body is exposed to light, it becomes more striking here than in our own country." So among the inhabitants of Central Europe, it appears that a considerable modification in complexion has occurred, which is not sufficiently accounted for by the climatic change that has taken place in it since the classical epoch. For the Germanic nations were unanimously described by ancient authors as exceedingly fair, possessing yellow or red hair, and blue or grey eyes; but these characters are now far from being prevalent among them, and it is only amongst the Scandinavian races that they are common to the mass of the people.

On the whole, then, it must be concluded that the Colour of the Skin is a character of such variable nature, that no positive line of demarcation can be drawn by its aid between the different races of mankind; and whilst it must be freely admitted that we are far from comprehending all the influences which operate to modify it, there seems ample evidence that climatic variations, whose agency is exerted for a sufficiently long period, are among the most efficient. This statement is obviously not invalidated by the fact, that Negroes and other dark-skinned people, who have lived for some time in temperate climates, have not lost their characteristic hue. For there is no example on record, so far as the author is aware, in which a Negro tribe or set of families has maintained itself for even three or four generations in a temperate climate, without intermixture either with the surrounding "whites" or with "blacks" of more immediate tropical descent. And until it shall have been shown that a continuous descent of many generations has taken place, in a group of Negroes completely isolated from the parent stock, and exposed to the conditions which are presumed to favour the production of the xanthous variety, *without* any considerable departure from their present complexion, there will be no negative evidence at all equivalent in probative value to the facts already cited on the affirmative side of the question.

5. We have now to inquire into the characters furnished by the colour, texture, and mode of growth *of the Hair*, which have been much relied on by some writers, as more permanent and distinctive than those furnished by the hue of the skin. Thus, the Negro is usually characterised by his "woolly" hair; while the Mongolian races are affirmed to be peculiar in the scantiness of their pilous covering; and the Hottentots are further separated by its tufted arrangement, which has been compared to the mode in which the bristles are set in a scrubbing-brush.—Now in regard to the *colour* of the hair, it is scarcely necessary to remark that it cannot be taken alone as a distinctive character of races; since it is liable to present the most extreme variations within the limits of any one. Among the xanthous Anglo-Saxons, for example, jet-black hair is by no means uncommon; although various shades of brown are most frequently met with. Among Negroes, on the other hand, it is not at all rare to meet with a more or less complete departure from what may be freely admitted to be the prevalent character of their race. In the instances which have been already cited as proving the want of constancy in the complexion of the dark or *melanic* races, a corresponding change manifests itself in the colour of the hair, which often becomes of a reddish brown, or even of a much lighter hue. These may occur in individuals, or in whole tribes. Thus, Dr. Pickering speaks of having seen two children, in whom "the Negro aspect had so entirely disappeared, that they might have passed for the children of Europeans, but for the remarkable appearance of the hair," which he could "compare to nothing but a white fleece." * The Cinghalese, according to the testimony of Dr. Davy, present as many va-

* The Races of Man (Bohn's edition), p. 188

rieties of hair as they do of complexion; its hue ranging through black and brown to red and even flaxen: and precisely the same is true of the Tahitians and Marquesans among the Oceanic race, as well as among many other nations. The *texture* and *mode of growth* of the hair, however, are characters on which it would appear, at first sight, that more reliance may be placed. The pilous covering may be described as "woolly," "crisped" or "frizzled," "flowing" or "wavy," and "straight." The African and Oceanic Negroes alone are characterised by "woolly" hair; the Australians, Abyssinians, and many African nations, usually have the hair more or less "crisped" or "frizzled;" among the Indo-Europeans, the "flowing" or "wavy" character prevails; while a peculiar straightness most commonly presents itself among nations of Mongolian descent. It is obvious, however, that these several terms express little more than differences in degree. For if "straight" hair has a slight tendency to curl, it becomes "wavy;" if this tendency be increased, it is commonly termed "curly;" the "crisped" or "frizzled" hair is little else than hair with a peculiarly stiff and close curl; and the "woolly" covering of the head of the Negro is by no means so different from the crisped hair of other dark races, as the designation given to it would imply, the chief difference consisting in its closeness of texture and its tendency to mat together. As Dr. Prichard has correctly stated, it is clearly shown by microscopic observation that the hair of the Negro is not really "wool," and it presents no constant structural difference from the jet-black hair which is not uncommon among Europeans. It has lately been asserted, however, by Dr. P. A. Browne, of Philadelphia, that the following definite structural differences do exist: — "The hair of the white man presents an *oval* section; that of the Choctaw and some other American Indians is cylindrical; that of the Negro is eccentrically elliptical or flat. The hair of the white man, besides its cortex and intermediate fibres, has a central canal, which contains the colouring matter, when present. The wool of the Negro has no central canal, and the colouring matter is diffused, when present, either throughout the cortex, or this and the intermediate fibres. In hair the enveloping scales are comparatively few, smooth of surface, rounded at their points, and closely embrace the shaft; in wool they are numerous, rough, sharp-pointed, and project from the shaft. Hence the hair of the white man will not felt; the wool of the Negro will."* Now, upon this it may be remarked that neither of the characters specified by Dr. Browne will stand the test of extensive observation. The *form* of the shaft, as shown in transverse section, varies greatly in the hairs of the same race, and even in those of the same individual; for not only is it sometimes round, sometimes oval, and (though more rarely) eccentrically elliptic or nearly flat; but it may be even reniform, or channelled on one side, a variety of which Dr. Browne takes no notice, except as occurring in the Hottentot. The *central canal* of the hair, which is occupied by medullary cells, is an extremely variable character; being often undistinguishable in the hair of the white races. Moreover, the *pigmentary matter* is sometimes almost exclusively confined to the cells of the central canal; sometimes it is equally diffused through the whole fibrous substance forming the shaft of the hair: and sometimes we have even seen it in greatest abundance towards the periphery, the centre being pale. Hence the elliptical section, the absence of "central canal," and the diffusion of pigmentary matter through the hair, are not in the least degree peculiar to the Negro, and cannot be regarded as characteristic of his hair. So, again, the writer takes upon himself to assert that there is not a greater difference in the degree of serration on the surface (which is due to the imbricated arrangement of the scales forming the cortical layer) between the hair of the Negro and that of other races, than exists among the individuals of any one race; and that the Negro's hair does not approximate more closely to wool in this respect, than the Negro's cranium does to that of the chimpanzee. The only constant peculiarity of the Negro's hair is the tendency to a close curl; and this seems connected with its form. As a general rule it may be stated that the roundest hairs curl least, and that those which show most flattening are the most disposed to curvature in their growth. But that there is something also in the nutrition of the hair which influences its mode of growth, appears from the following fact stated by Mr. Erasmus Wilson as the result of extensive observations: — "I have collected several instances in which the hair, naturally possessing a strong curl, becomes lank and straight if its possessor be out of health; the straightness of the hair becoming as certain an index of a disordered state of the economy, as a yellow eye-ball or a white tongue."*

Now if we attempt to apply the texture of the hair to the discrimination of races, we find that although it has a certain value as affording a character of *general* applicability, yet that this will not bear being carried too minutely into particulars. Thus, among the African nations, there are many whose affinity to the Negro race cannot be questioned, and which yet have merely "crisped" or "frizzled" hair, instead of a woolly covering; and there are others which cannot be shown on any other grounds to have a different descent, among whom the hair is long and flowing. On the other hand, we not unfrequently meet with individuals among the Anglo-Saxon race, in whom the hair is not merely curly, but "frizzled," and almost "woolly" in its texture. Among the Oceanic races, again, there is every gradation of the same kind;

* Transactions of the American Medical Association, vol. iii. p. 62.

* On the Management of the Skin, 3d ed. p. 77.

and great varieties present themselves within the limits of any one tribe. Here, too, the influence of external conditions shows itself in a very marked degree; for it is among the inhabitants of the lower levels bordering on the sea, between the tropics, who are most exposed to the vertical rays of the sun, their climatic conditions being nearly allied to those of the Negro, that the "woolly" character most remarkably shows itself; whilst in other tribes of the same race, which are not less prognathous, but live in higher and drier situations, the hair is only "frizzled," or even becomes long and wavy. Even if, as Dr. Prichard justly remarks, the hair of the Negro were really analogous to wool, it would by no means prove the Negro to be a peculiar and separate stock, unless the peculiarity were *constantly* presented by all the nations of similar descent; and were restricted to them alone; for, as already pointed out, there are breeds of domesticated animals which bear wool, whilst others of the same species, under different climatic influences, are covered with long straight hair. It is not unimportant to notice, that wool is occasionally borne by the dog, ox, and hog, to neither of which it is natural; whilst the sheep, whose ordinary covering is composed of it, occasionally exchange it for long straight hair. These facts so unequivocally prove that the texture of the hair is peculiarly liable to be influenced by external conditions, that it could only be on the strictest proof of *invariability*, that such a character could be properly adopted as a basis for specific distinction.

As examples in which there is historical evidence of alteration in the texture and mode of growth of the hair, it will be sufficient to refer to the case of the Barábras already cited, whose hair, originally woolly, has become longer and straighter, only retaining a slight crispness; and to that of the Western Turks, whose chins are furnished with flowing beards, in which their Eastern relatives are almost entirely deficient.

The greatest peculiarity in the growth of the hair is exhibited by the Hottentot race. The following account of its appearance in a young Bushman, who recently died in the United States, is given by Dr. Parsons*: — "His hair lay in little distinct, compact, curly tufts, twisted spirally; and in the intervals of these tufts, the skin was distinctly seen. The filaments were very fine, some of them five inches long, and black. They contained a distinct cortex and granular medulla. The transverse section of a filament resembled that of the Negro's, except in being concave on one of the two longer sides of the ellipse," or reniform. Thus, in the texture of the hair itself, the Hottentot seems allied to the Negro, whilst its sparseness reminds us of the scantiness by which the Mongolian races are generally characterised. We shall hereafter see, that there is strong reason for regarding the Hottentot race as of kin to the Negro; and for attributing the modification which it has undergone to the external conditions of its existence. The peculiar character of the *chevelure* of the Papuans, which will be noticed in the account of that race, seems to be chiefly due to its artificial treatment.

* Transactions of the American Medical Association, vol. iii. p. 62.

From the Anatomical portion of our inquiry, then, we are led to the general conclusion, *first*, that no such difference exists in the external conformation or internal structure of the different Races of Men, as would justify the assertion of their distinct origin; and, *secondly*, that although the comparison of the structural characters of races does not furnish any positive evidence of their descent from a common stock, it proves that even if their stocks *were* originally distinct, there could have been no essential difference between them, the descendants of any one such stock being able to assume the characters of another.

Of the next subject for investigation, the *Physiological* conformity or diversity of the several races of mankind, a much briefer summary will be sufficient. This part of the inquiry has been pursued with great diligence and success by Dr. Prichard*, who lays it down as a general axiom (the truth of which must be admitted by all who are competent to form an opinion on the subject, its validity being confirmed by the careful study of those races of domesticated animals which are remarkable for the greatest amount of *anatomical* variation), that the great laws of the vital functions, such as those expressing the periods and duration of life, the economy of the sexes, and the phenomena of parturition and reproduction, are, with slight deviations resulting from external agencies, constant and uniform in each particular species; whilst there are usually decided differences in regard to the same peculiarities among races of animals, which, though nearly resembling each other, are yet specifically distinct.

Now, taking the *average duration of life* as the first point of comparison, it has been shown by Dr. Prichard, that, whilst there is a marked difference in this respect between man and the highest apes — the full term of existence of the chimpanzee being stated by M. Lesson at not more than thirty years, and that of inferior species being less, — there is absolutely no difference among the several races of mankind, the *extreme* age of the Negro and American races being at least as great as that of the European, with the same *average* duration of life under the same circumstances as regards climate, mode of life, &c.

The age at which the body attains its full development, also, appears to be the same amongst different races; or, at any rate, does not differ more than among the different individuals of the same race. The inquiry into *the epoch of the first menstruation* has been most industriously prosecuted by Mr. Ro-

* Physical History of Mankind, vol. i.

berton; and its results, published from time to time, as they were obtained, have been lately collected in a form which admits of easy comparison.* It appears, from the evidence which he has brought together, that there is no considerable difference either in the *average* period of puberty, or in the *earliest* date of menstruation, among the greater number of tribes who are scattered over the whole of the habitable globe, from the equatorial to the polar regions; and that neither has a cold climate that influence in retarding it, nor a warm one in accelerating it, which is popularly attributed to these agencies respectively. The only well-marked exception to this general rule, occurs in the case of the Hindoo females, among whom the first menstruation occurs *on the average* about two years earlier than in this country. But this only arises from the fact, that a *larger proportion* of first menstruations among Hindoo females, takes place in the *earlier* years of that period, over which the commencement of puberty is distributed in European females, the distribution in the latter being more equable, as will be seen by the following table, furnished by Mr. Roberton:—

Ages.	Hindustan.	England.
8	3	—
9	8	14
10	18	55
11	80	77
12	145	142
13	139	263
14	105	396
15	45	417
16	24	340
17	18	215
18	5	138
19	3	65
20	1	33
21	2	9
22	—	4
23	1	1
	597	2169

For whilst the average age of puberty in the Hindoo female is thirteen years, and in the British, fourteen years eleven months, the per-centage of menstruations under eleven years is nearly the same in the two countries, so that the current idea of the *very early* puberty of Hindoo females is quite incorrect; and the difference in the average solely arises from the fact, that the greatest number of first menstruations occur among Hindoo females in the twelfth, thirteenth, and fourteenth years, whilst among the females of this country the larger proportion presents itself in the fourteenth, fifteenth, and sixteenth years. Now this difference, as Mr. Roberton justly remarks, cannot be attributed to climate, for Demerara and the West Indian Islands have a higher mean annual temperature than Calcutta and the Dekhan; and yet we know that the Negresses in these colonies are not earlier than the peasant women in England. A more probable cause, however, lies in the peculiar habits of the natives of that country, which tend, in more ways than one, to force forward the period of puberty. "It is the law of the Shastras, that females shall be given in marriage *before* the occurrence of menstruation, and that, should consummation not take place until after this event, the marriage is a sin. Accordingly, it is the custom in Lower Bengal to send the girl at the age of nine years to the house of her husband, unless the latter be so distant that it cannot be done; and two ancient Hindoo sages are of opinion, that if the marriage is not consummated before the first appearance of the catamenia, the girl becomes 'degraded in rank.' At Bangalore it would seem that this revolting custom does not obtain, the husband refraining from taking his wife to his own house till not less than sixteen days have elapsed subsequently to puberty."* Now, it can scarcely be questioned that such a premature sexual excitement will have a tendency to accelerate the epoch of puberty; and that, when this is constantly acting through a long succession of generations, an early puberty may come to be a character of *race.* But besides this *modus operandi* of the custom in question, the following has been pointed out by Mr. Roberton:—"When it is recollected that the consummation of marriage among the Hindoos has taken place, at the latest, on the arrival of puberty, during a lapse of more than three thousand years, and that the practice is sanctioned by ancient laws and consecrated by custom, it is easy to conceive that those females who were latest in reaching puberty, would be the least sought after for wives,—that such women would not be unlikely, in many instances, to remain unmarried,—and that thus (owing to the origination of a preference on this ground in the selection of their wives, operating through a long period of time) Hindoo women would gradually come to consist, in a proportion different from that in Europe or elsewhere, of such as by constitution are early nubile. To me there seems nothing extravagant or far-fetched in this supposition. The production of a like state of things in England, in any particular district, is quite conceivable. Nothing is better established, than that early (or late) puberty is a family peculiarity. Let us, then, only suppose families, possessing this kind of constitution, to intermarry, and the peculiarity in question would be propagated, extended, and transmitted; and so a race, distinguished by it, would be produced."† It is a justification of this view, that the mean age of puberty should differ in Bengal and the Dekhan, to the extent of nearly a year, being twelve years six months in the former province, and thirteen years five months in the latter, notwithstanding its warmer latitude; for, as just stated,

* Essays and Notes on the Physiology and Diseases of Women, and on Practical Midwifery. 8vo. London, 1851.

* Op. cit. p. 131.

† Op. cit. p. 129.

although formal marriages take place at a very early age throughout India, the custom is so far modified in the Dekhan, that consummation is not effected until after the first menstruation has appeared.

The *frequency of the catamenial flux*, and the *epoch of life to which it extends*, appear from Mr. Roberton's inquiries, to be no less constant among different races. It is quite true that the period of child-bearing is sooner terminated among the women of many tribes, especially in tropical climates, than it usually is in this country; but this is fairly attributable to the earlier marriages, and the consequently premature excitement of the generative power, of which its earlier decline is the natural consequence. The same is continually seen in this country. The marked difference in this respect, that arises out of laws and customs affecting the marriage state, is shown by the fact, that in India the mean age for a first parturition is 15½ years, whilst among 500 Manchester female operatives, tabulated by Mr. Roberton, the mean age was found to be 23 years. Some very curious evidence has been collected by that gentleman, which goes to prove that marriages nearly as premature as those of Hindoo females were formerly sanctioned by law and public opinion in this country; and that in Ireland they have been by no means unfrequent within a recent period.

The *duration of pregnancy* is well known to be the same throughout all the races of mankind; and this is a fact of peculiar importance, as a difference in this respect is elsewhere observable between species that are in other respects closely allied.

The *fertility of hybrid races*, originating in the intermixture of two races whose affinity is most remote, is a fact of which there can be no doubt whatever; and there is strong reason to believe that those hybrid races, the parents of which are Europeans on one side, and the aborigines of any country on the other, are generally destined to become the dominant population of those countries. For, on the one hand, these "half-castes" very commonly combine the best attributes of the two races from whose admixture they sprang; namely, the intelligence and mental activity of the European, and the climatic adaptation of the native.* And they are also in general distinguished for their fertility, when paired with each other, so that they are rapidly rising into numerical importance. On the other hand, this very intermixture, taking place as it usually does between an European father and a native mother, tends to diminish the number of the native population in a very remarkable manner; for there is now a large amount of evidence, that when a native female of the American or Polynesian races has once been impregnated by an European male, she thenceforth loses all power of conception from intercourse with the male of her own race. This was first pointedly stated by that very intelligent traveller, the Count de Strzelecki, who has lived much among different races of aborigines, the natives of Canada, of the United States, of California, Mexico, the South American Republics, the Marquesas, Sandwich, and Society Islands, New Zealand, and Australia, and who affirms that in *hundreds of cases* of this kind into which he has inquired, and of which he preserves memoranda, there has not been a single exception.*

As regards Australia and New Zealand, this statement, strange as it seems at first sight, has been fully borne out by independent evidence; and it offers the most complete explanation yet given, of the very rapid decrease in the native population of the various islands of Oceania, in which European races have been long established. Nothing precisely analogous is known in any other case. Instances of the influence of the father of a first offspring upon subsequent offspring by another father, are so frequent, as to have given rise to a current belief among the breeders of domesticated animals, that such is the fact; and the very ingenious hypothesis has been suggested by Mr. M'Gillivray, and ably advocated by Dr. Harvey, that the female parent in such a case becomes inoculated with the qualities of the male, through the blood of the fœtus, which partakes of the latter. But there is no known case, in which impregnation of a female by a male of a different species or variety has rendered her subsequently infertile to males of her own; on the contrary, the facts just referred to, as to the extension of the influence of the first father over the subsequent progeny, indicate that such is not the case. Hence this peculiarity affords no ground whatever for the establishment of a specific distinction between the two races; and the invalidity of such a distinction is at once indicated by the fact, that the peculiarity in question does not hold good in regard to the African races, the fertility of the Negro female with the male of her own race not being apparently impaired by previous fruitful intercourse with the European male, a kind of intercourse which is notoriously common in the West India Islands, and in the slave-holding states of North and South America.†

* This is well seen in the case of the descendants of the mutineers of the Bounty and of Tahitian women, who now occupy Pitcairn's Island.

* See the Count de Strzelecki's Physical Description of New South Wales and Van Dieman's Land, pp. 345—347.; and Dr. Harvey's Papers on the Inoculation of the Maternal System with the Peculiarities of the Paternal, through the Fœtus in Utero, in the Edinb. Monthly Journal for October, 1849, and October and November, 1850.

† It may be, as suggested by Dr. Harvey (loc. cit.), that the final purpose of this curious provision should be to replace the least improvable races by a population of a much higher order; the aboriginals thus becoming extinct without violence, but in the natural course of things; and their places being occupied either by half-breeds or Europeans. And, on the other hand, the immunity of the Negro may be designed to preserve his tenure of those parts of the earth, whether in subserviency to the European or independently of him, where, by reason of the

The *Psychical* comparison of the various races of mankind is really, in a practical point of view, the most important department of the whole investigation; and yet it has been the most neglected, until Dr. Prichard took up the inquiry. Whilst the capaciousness of the skulls of the Negro and European has been measured and compared, but little account has been taken of the workings of the brains which they contained. The colour of the skin, the flatness or projection of the nose, the lankness or crispness of the hair, the straightness or curvature of the limbs, have been scrutinised and contrasted, as if these alone constituted the proper description of Man; though it is surely in his mental character and its manifestations, that the attributes of humanity peculiarly consist.

The tests by which we recognise the claims of the outcast and degraded of our own country to a common humanity, are surely the same as those by which we should estimate the true relation of the Negro, the Bushman, or the Australian, to the cultivated European. We must not judge of their capabilities solely by their manner of life, however wretched that may be; since this is often, in great degree, forced upon them by external circumstances. Nor have we any right to pronounce them incapable of entertaining any particular class of ideas, simply because we cannot find the traces of these in their existing forms of expression. It is only when such people have been attentively studied — not by passing travellers, who, though they may pick up a little of their language, see little of their inner life, — but by residents who have succeeded in gaining acquaintance with habits which a jealous reserve would conceal, and ideas which the imperfections of language render most difficult of transmission *, that we have any right to affirm what they *are*; and even this amount of information affords little means of judging what they may *become*.

It will be only when the effect of education, intellectual, moral, and religious, has been fairly tested, that we shall be entitled to speak of any essential and constant psychical difference between ourselves and the most degraded beings clothed in a human form. It will only be when the influence of a perfect equality in civilisation and social position has been ineffectually brought to bear upon them for several consecutive generations, that we shall be entitled to say, of the Negro or of any other race, that it is separated by an "impassable barrier" from those which arrogate to themselves an inalienable superiority in intellectual and moral endowments. All our present knowledge on this subject tends to show that no such barrier exists, and that there is a real community of psychical characters among the different races of men; the differences in the degree of their positive and relative development, not being greater than those which exist in the successive or contemporaneous varieties of our own race. And it may be added, too, that in almost every instance, the more we learn concerning any particular nation or tribe reputed to possess the meanest possible aspect of humanity, the more we generally have to recede from the harshness of our first impressions.

A very striking example of the near affinity that may exist between the most degraded "outcasts of humanity," and races considerably advanced in civilisation and intelligence, is presented by the relationship of the Bushmen of the Cape of Good Hope to the Hottentot population which tenanted that region previously to the arrival of European colonists. The following is a graphic account recently given of them by one who has had ample opportunities of observation: — "The Dutch Boer, the Griqua, the Bechuana, the Kaffir, all entertain the same dread of, and aversion to, these dwarfish hordes, who, armed with their diminutive bows and poisoned arrows, recklessly plunder and devastate, without regard either to nation or colour, and are in their turn hunted down and destroyed like beasts of prey, which in many respects they so nearly resemble. . . . Time, a knowledge of, and an occasional intercourse with, people more civilised than themselves, have made little change in the habits and disposition of this extraordinary race. The Bushman still continues unrelentingly to plunder, and cruelly to destroy, whenever the opportunity presents itself. His residence is still amongst inaccessible hills, in the rude cave or cleft of the rock — on the level karroo, in the shallow burrow, scooped out with a stick, and sheltered with a frail mat. He still, with deadly effect, draws his diminutive bow, and shoots his poisoned arrows against man and beast. Disdaining labour of any kind, he seizes when he can on the farmers' herds and flocks, recklessly destroys what he cannot devour, wallows for consecutive days with vultures and jackals amidst the carcases of the slain, and, when fully gorged to the throat, slumbers in lethargic stupor like a wild beast, till, aroused by hunger, he is compelled to wander forth again in quest of prey. When he cannot plunder cattle, he eagerly pursues the denizens of the waste, feasts indifferently on the lion or the hedgehog, and, failing such dainty morsels, philosophically contents himself with roots, bulbs, locusts, ants, pieces of hide steeped in water, or, as a last resource, he tightens his 'girdle of famine,' and, as Pringle says, —

> 'He lays him down, to sleep away,
> In languid trance, the weary day.'

Whether this precarious mode of existence may, or may not, have influenced the personal appearance and stature of the Bushmen it is

high temperature, the European cannot toil in the way or to the degree which the cultivation of those regions requires.

* A curious example of the difficulty of fully comprehending the import of abstract terms, in a language which has been so much studied, both by linguists and by philologists, as the Chinese, will be found in the Athenæum for March 1. 1851.

difficult to say, but a more wretched-looking set of beings cannot easily be imagined. The average height of the men is considerably under five feet, that of the women little exceeding four. Their shameless state of nearly complete nudity, their brutalised habits of voracity, filth, and cruelty of disposition, appear to place them completely on a level with the brute creation, whilst the 'clicking' tones of a language, composed of the most unpronounceable and discordant noises, more resemble the jabbering of apes than sounds uttered by human beings."*

Now, there is ample evidence that the Cape Bushmen are a degraded caste of the Hottentot race. They agree with the Hottentots in all the peculiarities of physiognomy, cranial conformation, &c., by which the latter are characterised; and a careful comparison of the languages of the two races has shown that there is an essential affinity between them. It has been ascertained by Dr. Andrew Smith, that many of the Bushman hordes vary their speech designedly, by affecting a singular mode of utterance (employing the peculiar clapping or clicking of the tongue, which is characteristic of the Hottentot language, so incessantly, that they seem to be giving utterance to a jargon consisting of an uninterrupted succession of claps), and even adopting new words, in order to make their meaning unintelligible to all but the members of their own community. According to the same authority, nearly all the South African tribes who have made any advances in civilisation, are surrounded by more barbarous hordes, whose abodes are in the wilderness and in the fastnesses of mountains and forests, and who constantly recruit their numbers by such fugitives as crime and destitution may have driven from their own more honest and thriving communities. In this manner it has happened that within a comparatively recent period many tribes of Hottentots have been degraded into Bushmen, through the oppressions to which they have been subjected at the hands of their more civilised neighbours.

Now, although of the Hottentots themselves we are accustomed to form a very low estimate,—our ideas of them having been chiefly derived from the intercourse of the Cape settlers with the tribes which have been their nearest neighbours, and which have unfortunately undergone that deterioration which is so often found to be the first result of the contact of civilised with comparatively savage nations,—it appears from the accounts of them given by Dutch writers at the time of the first settlement of the Cape, that they were a people considerably advanced in civilisation, and possessed of many estimable qualities. Their besetting sins seem to be indolence and a love of drink (in this respect strongly resembling the Irish); yet when they can be induced to apply, they show no want of capacity or vigour. The testimony of Lieut.-Col. Napier is very strong as to their merits as soldiers when officered by Europeans; "and it has been," he says, "on the Cape Mounted Rifles, composed chiefly of this race, that many of the greatest hardships, fatigues, and dangers of the last and former Kaffir wars have principally fallen."* It has been frequently said that the Hottentots differ from the higher races, in their incapacity to form or to receive religious ideas. This is, however, by no means true. The early Dutch settlers describe them as having a definite religion of their own; and it was their obstinate adhesion to this, which was the real obstacle to the introduction of Christianity among them. When the attempt was perseveringly made and rightly directed, the Hottentot nation lent a more willing ear than any other race in a similar condition has done to the preaching of Christianity; and no people has been more strikingly and speedily improved by its reception.

Now, if we compare the condition of these people with that of the lowest members of the population of countries that claim to be most advanced in civilisation, we find that the difference is not so great as it might at first appear. Unfortunately, there is scarcely a civilised nation, in the very bosom of which there does not exist an outcast population, neither less reckless, nor less prone to the indulgence of their worst passions, than the miserable Bushmen, and only restrained from breaking loose by external coercion. The want of forethought and wild desire of revenge, which are said to be among the most striking characteristics of the Bushmen, are scarcely less characteristic of those *classes dangereuses*, which, as often as the arm of the law is paralysed, issue from the unknown deserts of our great towns, and rival in their excesses of wanton cruelty, the most terrible exhibitions of barbarian inhumanity. So, again, there is nothing in the inaptitude of any barbarous tribe for religious impressions, which surpasses that of the young heathens of our own land, who, when first induced to attend a "ragged school," are recorded to have mingled "Jim Crow" with the strains of adoration in which they were invited to join, and to have done their best, by grimaces and gestures, to distract the attention of those who were fixing their thoughts on the solemn offering of prayer; or of those who, after having joined with apparent sincerity in religious worship, simultaneously took their departure as the hour approached for the breaking up of the city congregations, in order that they might "go to work," as they expressed it; that is, that they might exert their thievish ingenuity upon the dispersing crowds. Now if, on the one hand, we admit the influence of want, ignorance, and neglect, in accounting for the debasement of the savages of our own

* Lieut.-Colonel E. E. Napier's Excursions in Southern Africa.

* The conduct of this corps in the recent outbreak (March 20. 1851), is stated by the Governor to have been most admirable. It was under its escort alone, that he forced his way through a country entirely in possession of the Kaffirs.

great towns, and yet cherish the belief that, so far from being irreclaimable, they may at least be brought up to the standard from which they have degenerated; on the other hand, we cannot well doubt the operation of the same causes on the outcasts of the Hottentot races, or refuse to believe that even the wretched Bushmen might be brought back at least to the original condition of the people from among whom they have been driven forth.*

It may be freely admitted that the different races of mankind exhibit very different degrees of capacity for intellectual, moral, and social improvement; but this difference is not greater than that which exists amongst individuals of the most favoured races, and cannot for a moment be assumed as the basis for specific distinctions between them. If the Negro, for example, is at present far behind the European standard, yet, under favourable circumstances, the intellect and moral character of individual Negroes have been elevated to it; while, on the other hand, we have too frequent proof that the intellect and moral character of the European are capable, not merely in individuals, but in families and groups of people, of sinking even below the average African standard. It is the observation of all who have had experience in the education of the *children* of races reputed to be inferior, such as Negroes, Hottentots, and Australians, that their capacity is at least equal to that of the lowest class of our own youthful town population, and that their docility is, if anything, greater. That this mental development is generally checked at an early age, and that the adults of these races too frequently remain through life in the condition of "children of a larger growth," may be freely conceded. But observation of the difference in developmental power, between the mind of the descendant of an educated ancestry, and that of the descendant of an ignorant and uncultivated peasantry, shows that within the limits of the same race the same difference may exist; and nothing is more likely to maintain it, than the absence of any encouragement to advancement, and the persistence, on the part of society at large, in the doctrine that the Negro *never can* be admitted within the pale of white civilisation.

Looking to the fact already mentioned (p. 1341.), as to the absence of that tendency to extinction in the African races, by sexual contamination from Europeans, which shows itself so remarkably among other aborigines, it is not a little interesting to observe, that there are elements in the Negro character, which have been deemed, by competent observers, capable of working a considerable improvement in even Anglo-Saxon civilisation. Many intelligent thinkers have come to the conclusion, that the boasted superiority of the latter is, after all, more intellectual than moral; and that in purity and disinterestedness of the affections, in childlike simplicity and gentleness of demeanour, in fact, in all the milder graces of the Christian temper, we may have even much to learn of the despised Negro. "I should expect," says Channing, "from the African race, if civilised, less energy, less courage, less intellectual originality than in ours; but more amiableness, tranquillity, gentleness, and content. They might not rise to an equality in outward condition, but would probably be a much happier race." And it is to be remembered that these and similar remarks have been made respecting the Negroes of the Guinea coast, or their descendants, who are, as we shall presently see, the most degraded of all the African races, except those of the neighbourhood of the Cape, whose degradation has been in great measure the result of European oppression, and the introduction of European vices. It

* This parallel, suggested by the writer of this article some time since (Edinburgh Review, Oct. 1848), has been recently followed up by the author of "London Labour and the London Poor;" who has shown that a remarkable correspondence exists in mental habitudes and mode of life, between the sonquas or paupers of the Hottentot race, and the wandering outcasts of our own, who possess nothing but what they acquire by depredation from the industrious, provident, and civilised portion of the community. The latter, like the former, have a secret or "slang" language of their own, adapted for the concealment of their designs; and, as already mentioned, they are generally characterised by the great development of the facial in proportion to that of the cranial part of the skull. The one tribe of "nomads," like the other, "is distinguished from civilised man, by his repugnance to regular and continuous labour; by his want of providence in laying up a store for the future; by his inability to perceive consequences ever so slightly removed from immediate apprehension; by his passion for stupifying herbs and roots, and, when possible, for intoxicating fermented liquors; by his extraordinary powers of enduring pain; by an immoderate love of gaming, frequently risking his own personal liberty upon a single cast; by his love of libidinous dances; by the pleasure he experiences in witnessing the suffering of sentient creatures; by his delight in warfare and all perilous sports; by his desire for vengeance; by the looseness of his notions as to property; by the absence of chastity among his women, and his disregard of female honour; and lastly, by his vague sense of religion, his rude idea of a Creator, and utter absence of all appreciation of the mercy of the Divine Spirit." It is further remarkable that the nomadic tribes seem to possess (sometimes hereditarily, sometimes as an acquired habit) such a constitutional adaptation to a wandering life, that, despite its privations, its dangers, and its hardships, they can rarely be induced to abandon it. It is well known that among the many instances in which the aborigines of Australia or of North America have been brought up and educated from an early age amongst Europeans, there are few, if any, in which they have been satisfied to to remain and to adopt the habits of civilised life. On approaching manhood, they become restless, and take the first opportunity of absconding to join their brethren in "the bush." So, again, there are numerous examples of white men adopting, by their own choice, all the usages of the Indian hunter or Australian bushman; and these, having once imbibed a fondness for the nomadic life, are as irreclaimable as those who have grown up in it. The same is the case, according to Mr. Mayhew, with a large proportion of the "street-folk" of London; who will give up situations affording comforts and advantages of a far superior order, to return to the indulgence of their wandering propensity.

is not a little remarkable that the earliest civilisation of which we have any distinct traces in the western portion of the Old World,—perhaps the very earliest development of the arts of life and of a spiritual philosophy that man has witnessed—should have presented itself in a race which was not only *African* in its locality, but also in its affinities, such being demonstrably the character of the *Ancient Egyptians*, as will be seen hereafter. Yet to this race the civilisation of Greece, of Rome, and of Western Europe may be in great measure ascribed; and long after the time when its power and intelligence had gained their highest state of development, the progenitors of the Anglo-Saxon race, both in Britain and in Germany, were in a state of barbaric ignorance and brutalism.

Referring, for the particulars of this part of the enquiry, to the valuable collection of information brought together by Dr. Prichard chiefly from the records of the Moravian missionaries who have planted themselves over almost every portion of the habitable globe, and who have gained a more intimate acquaintance with the mental habits and feelings of the people among whom they dwell, than has been acquired by any other class of European settlers; the following may be adopted as its general results:—In all the races of mankind, with which any adequate acquaintance has been gained, unequivocal indications may be discerned of the same moral and intellectual nature as that which the most civilised tribes exhibit; and these indications become more obvious, the more complete is our knowledge of their habits, not merely of action, but of thought. We can trace, in short, among all the tribes who are endowed with the faculty of articulate speech, the same rational, human nature; superior to that of the highest brutes, not merely in the complexity of the processes which it is capable of performing, but in that capacity for generating abstract ideas, and thus arriving at general principles, which, so far as we have the means of judgment, appears to be the distinguishing attribute of man. So, again, we discover in all of them the same elements of moral feeling; the same sympathies and susceptibilities of affection; the same conscience, or internal conviction of accountableness, more or less fully developed; the same sentiments of guilt and self-condemnation, and the same desire for expiation. These principles take very different forms of expression, even in civilised life; much more, therefore, ought we to be prepared for finding nothing more, even among the best specimens of uncivilised barbarism, than the mere rudiments of a higher understanding, and of a nobler moral nature, than that which they have at present reached. But the rudiments are there, though not always in the same degree of forwardness for being moulded to the institutions of a more regular society, for the development of the intellectual powers under a rational education, and for that growth of the moral and religious sentiments which Christianity is pre-eminently fitted to promote in every mind that opens itself to its benign influence.

The general conclusion, then, which we seem entitled to draw from the Anatomical, Physiological, and Psychological facts to which reference has been made, is that all the human races *may have had* a common origin; since they all possess the same constant characters, and differ only in those which can be shown to vary from generation to generation.—We have now to inquire, lastly, into the bearing of *philological* evidence upon the same question; and as this department of the inquiry is more foreign than the preceding to the character of the present work, a brief notice of its chief results is all that can be here admitted. These results, it may be remarked, are of extremely recent acquisition. In fact, there is no department of ethnology in which progress is at present so rapid, as it is in the study of glottology.

Now it may be observed, in the first place, that what has been just said of the community of *psychical* nature amongst the several races of mankind, is very strongly confirmed by the general fact of the universality of spoken language, and of the power of translating from one language to another. Dogs and monkeys *may* have languages of their own; but there is no such relation between these and ours, as may enable us to comprehend them; and where brute animals have been taught to comprehend human language, it has been only so far as to acquire a mental association between the sounds of certain words, and the material objects which they represent. This is but the first and simplest stage of the acquirement of language, as every one must perceive, who watches the development of the power of communication by this means, in early childhood. A very large part of all languages, but especially of those employed by nations advanced in intellectual culture, consists of terms expressive of *ideas* and *relations*, rather than of *material objects*; and it is in the capacity for expressing the former, that the distinctive attributes of *human* language appear specially to consist. This capacity, though existing more or less in all languages, will obviously vary considerably in degree, according to the intellectual culture of the people of whose thoughts they are the habitual expression; and the power of fully rendering the thoughts conveyed by one language into another tongue, must of course depend in great part upon the relative advancement of the two. The abstractions of a German transcendental philosopher do not always admit of being effectively conveyed, even in a tongue so nearly related as the English to their original, far less could they be translated into Hottentot gibberish. So, again, the peculiar style of eloquence cultivated in the East, does not produce its adequate effect, when rendered in Western tongues. But any two barbarous languages, or any two which are highly cultivated, are, on the whole, so pervaded by a sameness of character, as to bear witness to the similarity of their internal source.

The affinities between languages are sought by philologists in two entirely different directions; namely, in their *vocabularies*, and in their methods of *grammatical construction*. In comparing the former, it is of course necessary to make due allowance for the possible influence of conquest, intermixture, or frequent intercourse, in modifying the original tongues; but the experienced enquirer may generally eliminate this source of error, by placing his chief reliance on what are termed *primary words*, i. e. on words which serve to represent the universal ideas of a people in the most simple state of existence. Such are the terms expressive of family relations; the names of the most striking objects of the visible universe, the sun, moon, stars, trees, rivers, &c.; terms distinguishing the principal parts of the body, as the head, eyes, hands, and feet; the numerals, up to five, ten, or twenty; and verbs descriptive of the most common sensations and bodily acts, such as seeing, hearing, eating, drinking, sleeping. Such primary words are never wanting in the language of any nation; and it has been ascertained by observation, that they are the last to undergo change, either in the spontaneous modifications which take place in the course of time, or under the disturbing influence of a foreign idiom; so that a conformity in primary words affords very strong evidence of a community of origin among the nations which exhibit it.—The evidence afforded by conformity in grammatical construction, requires a more intimate acquaintance than is needed for the preceding, with what is sometimes called the *genius* of the language; but when it *has been* gained, it is frequently even more important than that furnished by the vocabularies. For there are many cases in which the latter are so continually undergoing important changes (the want of written records allowing them to possess no more than a *traditional* permanence), that the divergence of tongues becomes so great, in the course of even a few generations, as to prevent tribes descended from a common ancestry from understanding one another; and yet the system of grammatical construction, which depends more upon the grade of mental development, and upon the habits of thought, exhibits a remarkable permanence.

The following are the principal types of construction, or "methods by which the relation between the different words that constitute sentences is indicated," according to a very recent and distinguished authority.*

1. The *Aptotic* type, of which the Chinese is an example. In this, there is a total absence of inflections; and the words which, in languages of the classical form, do the work of the inflections, that is, express the relations of the principal words to each other, are themselves most commonly the names of objects and actions, *i. e.*, nouns and verbs. "Thus if," says Dr. Latham, "instead of saying, *I go* to *London*, *figs come* from *Turkey*, *the sun shines* through the *air*, we said *I go* end *London*, *figs come* origin *Turkey*, the *sun shines* passage *air*, we should discourse after the manner of the Chinese." This is the lowest grade of linguistic development.

2. The *Agglutinate* type, which is carried to its fullest extent in the American languages. These possess inflexions, which can be generally shown to have arisen out of the juxta-position and composition of different words, the incorporation not having been sufficiently complete wholly to disguise the originally independent and separate character of the inflexional addition. This may be regarded as a decided advance in development.

3. The *Amalgamate* type, of which the classical languages are the most perfect examples. These possess a very complete system of inflexions, which express the relation between the fundamental idea denoted by the term, and some other; and these inflexions are so completely incorporated with the root with which they are conjoined, that their existence as separate and independent words cannot be demonstrated, and can only be supported upon the analogy of the agglutinate languages. Thus, "in a word like *hominem*, there are two parts, *homin*, radical; *em*, inflexional. In the word *te-tig-i*, there are the same. The power of these parts is clear. The *tig-* and *homin-* denote the simple *action* or the simple *object*. The *te-* denotes the time in which it takes place; the *i*, the agent. In the proposition *te-tig-i homin-em*, the *em* denotes the *relation* between the object (the man touched) and the action (of touching). *Logically*, there are two ideas, *e. g.* that of the action or object, and that of the superadded conditions in respect to time, agency, and relation."

4. The *Anaptotic* type, of which the English is an example. This designation is given to languages which were once inflexional, but which have in great part ceased to be so. In such we find that the auxiliary words which do the work of the Greek and Latin inflexions, are not names of objects and actions like those of the Chinese language, but possess (generally speaking) a purely abstract value, having a meaning only when in context with other words. Thus, where the Roman said *te-tig-i*, we say, *I have touched*; where the Roman said *patri*, we say *to father*; where a Roman said *tangam*, we say, *I will* (or *shall*) *touch*. In many of these auxiliary words, however, an independent meaning can be clearly seen; thus *have* and *will* are obviously verbs in their own right; and the conjunction *if* is a corruption of the Saxon *gif* (give). Moreover, the inflexions are seldom or never wholly disused; so that these anaptotic languages always preserve relations of affinity to those of the two preceding types, of which they may be considered a peculiar development.

To one or other of these types, or to tran-

* Dr. R. G. Latham, on the Natural History of the Varieties of Man, p. 9.

sitional grades between them, it is believed that all existing languages may be referred. It is remarkable that the development of a language should not by any means correspond to the advance of civilisation, so far, at least, as this is manifested by progress in the arts of life. The Chinese, for instance, of all known languages, most completely preserves, in a fixed or stereotyped condition, that earliest phase in the development of speech, in which every word corresponded to, or represented, a substantial object in the outward world; and it cannot be denied that a considerable amount of intellectual development is to be found amidst that people. And from what is known of the ancient Egyptian language, this appears to have been nearly in the same condition. On the other hand, there are many languages of comparatively barbarous nations, even belonging to the same group with the Chinese, which possess much greater flexibility. The *highest* development of language however, is undoubtedly to be found coincident with the highest intellectual cultivation; since this pre-eminently shows itself in the Indo-European tongues, of which the Sanscrit may be taken as the type, the Hellenic presenting its highest development in the amalgamate form, and the English in the anaptotic. In both these do we find that the general plan of construction tends to give to every single word a fixed and definite meaning, and at the same time, to render it subservient to the general idea that the sentence is to unfold, which is obviously the great end and aim of language; whilst in the Chinese, every *spoken* word has an immense variety of meanings, and its import being determined, partly by its place in the sentence, partly by the tones or accents with which it is pronounced, and in the *written* language by an immense number of conventional signs derived from figurative sources, which are destined, not to express sounds, but to suggest ideas, and thus to assist the reader in guessing the meaning of the word.

Now the most positive evidence which philology is able to afford, in regard to the affinities of two languages, is undoubtedly that which is derived from their conformity both in vocabulary and in grammar. But it frequently happens that one of these kinds of evidence is deficient; and the degree of reliance that can be placed upon the other, taken alone, must depend greatly upon the circumstances of the individual case. Thus, if there be evidence that the vocabulary of one of these languages is in a state of continual change, an entire difference of vocabularies is no obstacle to the idea of the affinity between two languages, when this is decidedly indicated by a striking conformity in their systems of construction. On the other hand, when two languages or groups of languages differ greatly in their construction, but present a certain degree of verbal correspondence, full weight may be attached to that correspondence, if it can be proved that it has not been the result of intercourse subsequently to the divergence of the stock, and if it can be shown to be probable that their separation took place at a period when as yet the grammatical development of both languages was in its infancy. The first appears to be true of the American languages, which seem, as a whole, to be legitimately referable to a common stock, notwithstanding their complete verbal diversity. The second is the aspect under which it appears likely that the Indo-European or Japetic, and the Syro-Arabian or Semitic groups of languages will come to present themselves; the results of the recent labours of Rawlinson, Layard, Botta and others, on Eastern Archæology, tending decidedly in this direction.

Philological inquiry, then, must be looked to as the chief means of determining the question of radiation from a single centre or from multiple centres; and although, in the present state of this department of science it would be unsafe to venture on a positive conclusion, yet the following may be considered as the principal groups under which the various languages hitherto studied may be arranged.

1. The *Indo-European*, sometimes termed Indo-German, frequently *Japetic*, and by late writers Arian, or Iranian. This group comprehends nearly all the existing languages of Europe, and those of a portion of South-Western Asia.

2. The *Syro-Arabian*, often termed *Semitic;* which are spoken by a large part of the population of Syria, Arabia, and Northern and Eastern Africa.

3. The *Turanian*, or Ugro-Tartarian; which are spoken by the (Mongolian) people of High Asia and of certain parts of Northern Europe.

4. The *Seriform*, or Indo-Chinese; which are spoken by the people of South-Eastern Asia.

5. The *African;* which are spoken by the people of Central and Southern Africa.

6. The *Malayo-Polynesian;* which are spoken by the inhabitants of the numerous islands and island-continents of Oceania.

7. The *American;* which are spoken by the inhabitants of the New World, from the Arctic Sea to Cape Horn.

Now it is not a little curious that the linguistic affinity should often be strongest, where the conformity in physical characters is slightest, and weakest when *this* is strongest. Thus among the Malayo-Polynesian and the American races, as already remarked, there are very striking differences in conformation, features, complexion, &c.; and yet the linguistic affinity of the great mass of tribes forming each group is not now doubted by any philologist, though a doubt may still hang over some particular cases. On the other hand, the hiatus between the Turanian and the Seriform languages is very wide; but the physical conformity is so strong between the Chinese and the typical Mongolian nations, that no ethnologist has ever thought of assigning to them a distinct origin. So, again, there would seem to be no near relationship between the American and the Turanian languages; but the affinity of the two stocks appears to be established by the transition-link afforded by the Esquimaux, which are Mongolian in their conformation and American in their language. The affinity of the Semitic and Japetic languages, moreover, is so deeply hidden, as to have, until recently, almost defied discovery; and yet the people who speak them so far resemble one another in physical characters, that they have been almost invariably associated together under the general designation of the *Caucasian* race. The common origin of the inhabitants of the continents of Europe, Asia, and America is thus pointedly indicated by the combination of these two sources of evidence. The portion of the Malayo-Polynesian race, that is, in nearest proximity with South-Eastern Asia, presents such a striking resemblance in physical characters to the inhabitants of the neighbouring part of that great continent, that their community of origin can scarcely be doubted; and when certain points of resemblance between some of the Oceanic and Indian dialects are taken into account, this inference receives strong confirmation. The African nations have long been regarded as the most isolated from the common centre from which all the others appear to have radiated; but recent investigations have shown that such isolation has no real existence. For, on the one hand, there are tribes which form (like the Esquimaux) a connecting link between the Semitic and proper African families, being African in their conformation, but Semitic in their language; and, on the other, the study which has been recently bestowed on the proper African languages, especially by Dr. Latham, has shown them to have so much in common with the Semitic tongues, that, with the additional evidence derivable from community of certain usages, extending through vast areas physically isolated from each other, it now seems impossible to believe but that the African nations are nearly related to the Semitic, and are through them, derivable from the great Asiatic centre.

IV. General Survey of the principal Families of Mankind.

In the summary view which will now be presented, of the characters of the principal varieties of the human race, it will be convenient, in the first instance, to arrange them according to their existing geographical distribution, stating, under each head, the most important peculiarities in physical conformation, in psychical character, and in language, which they may respectively present. A general scheme of their probable relations of affinity will be subsequently given.

I. European Nations. — The collective body of European nations, with the exception of the Lapps, present a great uniformity in physical characters; for although minor differences exist among their subordinate groups, they all possess the elliptical cranium, the symmetrical form, the xanthous complexion, and the flowing hair, which characterise what is ordinarily designated as the *Caucasian* variety. This group of nations, however, must be primarily divided into those of *Arian* or *Indo-Median* origin, and those whose origin is probably or certainly *Mongolian.* Under the latter head may be ranked (as already remarked) the Lapps and Finns of Scandinavia; the Magyars of Hungary; the Turks of Turkey; not improbably the Basques or Euskaldunes of Biscay and Navarre; and (possibly) the Albanians or mountaineers of ancient Illyria and Epirus.* The European tribes of the Arian stock are considered by Dr. Latham as fundamentally divisible into the two great groups of *Celts* and *Indo-Germans.* The former seem to have detached themselves from the common stock, *before* the evolution of the language had proceeded to the formation of the cases of the nouns, but after that of the persons of the verbs had taken place †; and their language presents obvious traces of agglutination, which, as already shown, marks an early stage in linguistic developement. The eastern origin of the Celtic nations was first demonstrated by Dr. Prichard ‡, and has been subsequently more fully proved by Pictet.§ The typical Celts exhibit somewhat of that development of the malar bones, which is carried to its fullest extent in the pyramidal skull; and in their comparatively unprogressive psychical character they contrast remarkably with the Germanic group of nations. The Indo-Germans, on the other hand, seem to have detached themselves from the common stock *after* the evolution of the cases of nouns had taken place; and their language presents less evidence of agglutination than does the Celtic. The Eastern origin of this group of nations is not now doubted by any competent ethnologist; for their languages, in spite of their diversity, constitute but one philological group, being united alike by community in many of the most important primary words, and by general similarity of grammatical construction; and being obviously all formed upon the same base with the Sanscrit, if not upon that language itself. Of all extant European dialects, the Lettish and Lithuanian approach most nearly to the ancient Sanscrit; but a still nearer approach seems to have been presented by the old Prussian, a dialect now extinct, which maintained, to the sixteenth century, a very slightly changed form of the Zend or Median language, which was an early derivation from the Sanscrit. Whilst every one of the Indo-Germanic languages bears traits of

* See on this last point Dr. Latham's "Natural History of the Varieties of Man," p. 552.

† Op. cit. p. 529.

‡ On the Eastern Origin of the Celtic Nations, 1831.

§ De l'Affinité des Langues Celtiques avec le Sanscrit; Paris, 1837.

affinity with every other, each has been modified by the introduction of extraneous elements. Thus, in those of Western Europe, there is a considerable admixture of Celtic; whilst in others there are traces of more barbaric tongues. In fact, there can be little doubt, that Europe had an indigenous population before the immigration of the Indo-German or even of the Celtic tribes; and of this population it seems most probable that the Lapps and Finns of Scandinavia, and the Euskarians of the Biscayan provinces, are the remnant. There is evidence that the former of these tribes once extended much further south than at present; and, on the other hand, there is ample proof that the latter had formerly a very extensive distribution through Southern Europe. It has been clearly shown by William Von Humboldt, that the Euskarian language, so far from having been derived (as some writers have supposed) from the Celtic, must have been in existence long anterior to the immigration of the Celtic nations into Western Europe; and since that time, it has been shown to have affinities with the Finnish tongue, and through this with the languages of High Asia. It may be surmised, then, that the advance of the Indo-European tribes, from the south-east corner into central Europe, separated that portion of the aboriginal population, which they did not destroy or absorb, into two great divisions; of which one was gradually pressed northward and eastward, so as to be restricted to Finland and Lapland; and the other southward and westward, so as to be confined at the earliest historic period to a part of the peninsula of Spain and the South of France, gradually to be driven before the successive irruptions of the Celts, Romans, Arabians, and other nations, until their scanty remnant found an enduring refuge in the fastnesses of the Pyrenees.* It is curious that the Euskarian language should carry out the principle of agglutination to an extent which has no parallel among the languages of the Old World, and which is only surpassed by those of America.

The Indo-Germanic race are unquestionably those which are destined to acquire the greatest predominance, not only in the Old World, but in all those newly-found lands which have been discovered by their enterprise. With scarcely any exception, as Dr. Latham has justly remarked, they present an *encroaching* frontier; there being no instance of their permanent displacement by any other race, save in the case of the Arab dominion in Spain, which has long since ceased; in that of the Turkish dominion in Turkey and Asia Minor, which is evidently destined to expire at no distant period, being now upheld only by extraneous influence; and in that of the Magyars in Hungary, who only maintain their ground by their complete assimilation to the Indo-Germanic character. It has been already pointed out, however, that the rapid extension of this race is due, not merely to its superior skill in the arts of war and diplomacy, but to a physical cause which tends to extinguish the aboriginal population of many of the inferior races, wherever sexual intercourse takes place between them (p. 1341.).

II. Asiatic Nations. — Whilst in Europe the presence of the *Arian* family is the rule, and that of the *Mongolian* is the exception, we find in the vast continent of Asia, that the reverse is the case; the presence of the Arian family being the exception, and that of the Mongolian the rule. In fact, although the Celtic and Indo-Germanic races undoubtedly had their origin in Central or Western Asia, yet the tribes which can, with greatest probability, be regarded as the descendants of the ancient stock, are extremely few, and scarcely able to maintain their ground. They are, according to Dr. Latham, the *Persians* of Northern and Western Persia; the *Kurds*, the *Beluchi*, the *Affghans*, the *Tajiks* of Bokhara, and the *Sia-posh*. All these speak languages which contain a large proportion of Sanscrit words; but whether they are so far akin to the Sanscrit in grammatical structure, as to hold to it the same relation as that which the European languages possess, is as yet uncertain. Whether or not the Armenians belong to this group, has not yet been ascertained.* It has been generally considered, until recently, that the nations of the great Indian peninsula for the most part belonged to the same stock; but philological investigation has shown that such a doctrine is certainly untrue with regard to some, and is probably or possibly erroneous with regard to others. The Tamulian, which is the dominant language of Southern India, is undoubtedly not Sanscritic in its origin, although containing an infusion of Sanscritic words, but more closely approximates to the Seriform type. Many of the hill tribes, in different parts of India, speak peculiar dialects, which appear referable to the same stock. And in Dr. Latham's opinion, the dialects spoken throughout Northern India are to be regarded in a similar light, notwithstanding the large infusion of Sanscritic words which they contain. Viewed under this aspect, the mass of the population of India is

* This view, which was suggested by the Author (British and Foreign Medical Review, Oct. 1847) without the knowledge that it had been elsewhere propounded, has been put forth with considerable confidence by Dr. Latham (Varieties of Man, p. 551.) as originating with Arndt, and adopted by Rask, distinguished Scandinavian ethnologists. The great antiquity of the Albanian tongue having been fully proved, and the circumstances of the tribe having been nearly the same, it is suggested by Dr. Latham that this, too, may be a remnant of the aboriginal Turanian population.

* It is somewhat remarkable that greater attention should not have been paid to the study of the Armenian language; as the facilities presented by commercial intercourse are not small; and the isolated position of this nation is one which might lead to the anticipation, that its language might retain the Sanscritic type, with less alteration than that of other nations, which have been more affected by conquest and intermixture of races.

not to be regarded as Arian, but as Mongolian; and the introduction of the Sanscrit language was accomplished by an invading branch of the Arian stock, the only trace of which is to be found in the distinctness of the *Brahminical* portion of the Hindoo population, in whose religious and other writings the Sanscrit language is still preserved.

In the Asiatic group of Indo-Germanic nations, the same general type of conformation presents itself as in the European; there is, however, a much greater variety of complexion. The mountaineers, even within the tropics, are often as fair as Europeans; whilst those who live in the level plains, and are exposed to the full heat of the torrid zone, may be of a very deep brown or even black hue. The variety of complexion shown among the Hindoos, even in the Brahminical caste, has been already adverted to. There is but little to remind us of the Mongolian type in the countenances of the Hindoos, which are often remarkable for symmetrical beauty, that only want a more intellectual expression to render them extremely striking; some traces of it, however, may perhaps be found in the rather prominent zygomatic arches (*fig.* 828);

Fig. 828.

Hindoo Female of Pondicherry. (From a portrait in M. Geringer's "L'Inde Française.")

but this is a character which not unfrequently shows itself strongly in the Arian races (*e. g.* the Celts); and the cranial part of the skull presents no approach to the pyramidal type, being often very regularly elliptical. Among the southern inhabitants of the peninsula, however, a much greater departure from the Caucasian type presents itself; for not only is the colour darker, but the cheek bones are more prominent, the hair coarse, scanty, and straight, the nose flattened; and sometimes the lips are very thick, and the jaws project, so that we have indications of a transition towards both the pyramidal and the prognathous types.

The south-western portion of Asia is occupied by the Arabs and other *Semitic* races, which, as will be presently explained, form the transition between the proper *Asiatic* and proper *African* nations.

The whole remainder of the vast Asiatic continent is occupied by nations which present a sufficiently close approximation to each other, either in physical characters or in language, or in both, to justify their association in one extensive group, under the name of *Mongolidæ.* The typical character of this great family of nations, as seen in a Mongolian or a Tungus from Central Asia, consists in the pyramidal form of the skull (*fig.* 811. *et seq.*), with the broad flat face and prominent cheek-bones, and its antero-posterior diameter scarcely exceeding the parietal; the nose is flat, neither arched nor aquiline; the eyes drawn upwards at their outer angle (*fig.* 814.); the skin of a swarthy yellow; the hair straight and scanty, and the beard deficient; and the stature undersized. These characters are softened down in many members of the group; and may even be entirely wanting, as for instance, in the Circassians and Georgians, (p. 1328.), termed by Dr. Latham the Dioscurian Mongolidæ. Still they are very extensively distributed; and there is by no means the same amount of variation in complexion, under the influence of temperature, that is seen in the Indo-Germanic races. The following, according to Dr. Latham, are the principal groups into which the Asiatic nations may be arranged: — 1. The *Seriform* stock, distributed over China, Thibet, the Indo-Chinese peninsula, and the base of the Himalayan range of mountains; their configuration is Mongolian, softened down (*fig.* 829.); their languages

Fig. 829.

Skull of a Chinese Ladrone. (From a specimen in the Museum of the Royal College of Surgeons.)

are aptotic, or with only the rudiments of an inflexion; and they thus preserve more than any other race, the primitive condition of human speech. In their mode of life, they present the phenomenon of a civilization which has attained a considerable degree of development, remaining stationary through a very long period of time, and isolating itself as jealously as possible from the general current of progress. In passing from China towards India, there is a gradual transition in physical and mental characters, between the Chinese and the Hindoo; thus the Burmese have more hair and beard, more prominent features, and darker complexions, than the Siamese and Chinese; and the darkness in complexion increases towards the confines of Bengal. There is, therefore, no such abrupt transition, as shall make it difficult to admit the Seriform origin of the bulk of the Hindoo population, if further investigation of their language should render this connection as probable as it has already been shown to be in the case of the inhabitants of the Dekhan and Ceylon.—2. The *Turanian* stock, including the proper Mongolians of High Asia, the Tungusians, the Turks, and the Ugrians. Among these, the conformity in physical characters is extremely close, the only exception being in the case of the offsets which have migrated into Europe, and which have undergone transformation (as explained at p. 1327.) into the Caucasian type (*fig.*815*et seq.*). The languages of these people are not monosyllabic, but have not undergone any high development; and they are spoken with very little variation over extensive areas. The general character of the country inhabited by this group is remarkably uniform, being a series of high table-lands or *steppes*, well adapted for maintaining a nomadic pastoral population. Such is the general habit of these people, and such it has been from our earliest knowledge of them. The Tungusians, however, advance to the Polar Sea, and adopt a manner of life more resembling that of the proper Hyperborean races.—3. The *Peninsular Mongolidæ*, inhabiting the islands and peninsulas of the north-eastern coast of Asia, such as Korea, Japan, and Kamschatka. These are all Mongol in their conformation, but differ from the preceding in the character of their languages, which seem to be, in some cases, extremely *poly*-syllabic, always showing a strong tendency to agglutination, and thus showing a transition to the American languages, in which this peculiarity presents its highest development. These tribes are separated from each other, however, by considerable breaks in geographical continuity; some of them lying within the Arctic circle, and others as far south as 26° N. L. And they are not less distant in the two extremes of their social development, one section of the group partaking of the civilization of China, and another exhibiting the rudeness of the Samöied. This group is obviously not a typical, but a transitional one.—4. *Hyperborean Mongolidæ*, inhabiting the borders of the Icy Sea, especially in the neighbourhood of the courses of the large rivers, and subsisting especially by fishing and fur-hunting. The area which they occupy is not continuous; the principal tribes, known as the Samöiedes, the Yeniseians, and the Yukahiri, being separated from each other by the advance of the Northern Ugrians and Tungusians. Their conformation is Mongolian; but their growth is stunted, and their complexion swarthy; and they bear a very close resemblance to the Laplanders and Esquimaux. It is probable that they will be united when their languages shall have been more fully studied, either with the Turanian or with the Peninsular stocks.

Turning now to the *Syro-Arabian* or *Semitic* nations, which occupy a considerable area in the south-western part of Asia, we encounter a very different type of physical conformation, and a group of languages which is peculiar alike in its structure and in its vocabulary. Generally speaking, the people of this race exhibit a remarkable symmetry of form, and perfection of cranial organisation (*fig.* 830); and it

Fig. 830.

Arab of the Guard of the Imaun of Muscat. (*From a portrait taken by an officer of L'Artemise.*)

was remarked by Baron Larrey, who had ample opportunities for observation during the Egyptian expedition, that experience has proved to him that their psychical character is conformable to this high standard, a great aptitude for intellectual activity being combined with extraordinary acuteness in the use of the organs of sense. There can be no doubt whatever, that the Semitic races have exerted a most important influence on the civilization of the world; and this not merely by their own early progress in the arts of life (as shown by the extraordinary history of the Assyrian and Babylonian empires, on which so much new light has recently been cast); but also by having afforded the channel through which Monotheism was transmitted from the patriarchal times to that of Moses; by having served as the depository of the Mosaic dispensation, by which that Monotheism was preserved and organised in the Judaical system; and by having been the centre whence has emanated the fuller light of Christianity, which, in the fulness of time, was exhibited among a people blinded by their own prejudices and self-esteem, to be the regenerator of the nations that as yet knew not God. Scarcely less remarkable is it that the third great Monotheistic system—that of Mahommedanism—which is essentially a degraded mixture of Judaism and Christianity, should have developed itself amongst the same people, occupying the place, on the one hand, of its Divine prototypes, and on the other, of the various inferior religions whose professors have been brought under Arab sway, and forced to embrace the dogma of their conquerors. Wherever this last change has taken place, it has obviously been for the better; and there is no more striking example of it, than the superior condition of the African nations which have been thus brought under Mahommedan influence. And it can be scarcely doubted that it is the purpose of Divine Providence, thus to spread and to maintain a Monotheistic system, adapted to the capacities of the people who receive it; until a higher intellectual and moral development shall render them capable of appreciating the purer light of Christianity.

The Semitic languages early attained a considerable development; but the forms it took were not well adapted for further evolution; and they present nearly the same type at the present time, as that which is exhibited in the earliest literature which the world possesses: namely, the sacred books of the Hebrew nation. Their alphabet was the earliest in the world; and their writing is peculiar in passing in the direction contrary to that of other languages, namely, from right to left. "Of the several nations," remarks Dr. Prichard *, "who are connected by this community of language, some who were formerly celebrated have become nearly extinct; while others have spread themselves, either as the exiled followers of a persecuted faith, or as the enduring apostles of a victorious one, over the world, and seem destined, through the energy of their invincible mind, to survive to the end of time. The Syrian race scarcely exists; their language only survives in some districts on the borders of Kurdistan; everywhere they have been lost under the predominating Arabs. The Homerites in Arabia, if they there exist, are little known; the Abyssinian Homerites are the only inhabitants of the province of Tigre, to the eastward of the Tacazze, whose idiom still resembles the ancient Gheez. The Arabs, who spread Islam by their victories from the Atlantic to the Ganges, and the Jews, who are wanderers over the whole world, are perhaps now more numerous than were even their forefathers." Of the difference in complexion that manifests itself among the Arabs of Arabia, mention has already been made; the greatest modifications of the ordinary type present themselves, however, among the African members of the Semitic group, as will presently appear.

III. African Nations. — Of the various nations inhabiting the African continent, those of the *Negro* type are usually regarded as the most characteristic specimens. But, as Dr. Latham has justly remarked, "no fact is more necessary to be remembered, than the difference between the Negro and African; a fact which is well verified by reference to the map. Here the true Negro area, occupied by men of the black skin, thick lip, depressed nose, and woolly hair, is exceedingly small; as small in proportion to the rest of the continent, as the area of the district of the stunted Hyperboreans is in Asia, or that of the Lapps in Europe." When we have separated the region north of the Great Desert, which is mostly occupied by Semitic tribes; the Great Desert itself, whose scattered population is far from being Negro in many of its features; the valley of the Nile, at least in its middle and lower portions, including Egypt and Nubia, and even Abyssinia; and the Kaffre and Hottentot areas south of the equator; there is only left the western portion of the continent, including the alluvial valleys of the Senegal, the Gambia, and the Niger, with a narrow strip of central Africa, passing eastwards to the alluvial regions of the Upper Nile. Even within this area, the true Negro type of conformation is by no means universally prevalent; for many of the nations which inhabit it must be ranked as *sub-typical* Negroes. Our idea of the Negro character, in fact, is almost exclusively founded upon that division of the race which inhabits the low countries near the Slave Coast; such tribes, indolent and degraded in an extreme degree, are distinguished alike by their extreme ugliness, and by their brutal sensuality. The proper Negro character consists in the combination of a prognathous form of skull, with receding forehead and depressed nose, thick lips, woolly hair, black unctuous skin, and crooked legs; the facial aspect being such as is represented in *figs.* 803, 804. Similar characters are met with, again, among the inhabitants of the alluvial regions around Lake Tchad, in the interior; and some of the tribes in the lowest lands on the eastern side are but little superior. On the other hand, in the immediate neighbourhood of the typical Negroes, but inhabiting higher levels, and presenting a more advanced civilization, are found a number of tribes departing from the Negro type in one or more of its distinctive characters. Thus the race of Iolofs near the Senegal, and the Guber in the interior of Sudan, have woolly hair and deep black complexions, but fine forms and regular features of the European cast (*fig.* 831); the high parts of Senegambia, where the temperature is moderate and even cool at times, are inhabited by Fulahs of a light copper colour; and on nearly the same parallel, but at the

* Natural History of Man, p. 145.

Fig. 831.

Senegal Chief. (From a portrait taken by an officer in the expedition of Capt. Laplace.)

opposite sides of Africa, are the high plains of Enarea and Kaffa, where the inhabitants are said to be fairer than the natives of Southern Europe. So, again, whenever we hear of a Negro state, whose members have attained any considerable degree of improvement in their social condition, we constantly find that their physical characters deviate considerably from the strongly-marked or exaggerated type of the Negro; such are the Ashanti, the Sulima, and the Dahomans of Western Africa, of which last nation the king is described by a recent visitor (Lieut. Forbes) as many shades removed from black in his complexion, as having quite an intellectual expression of countenance, and as possessing a remarkable symmetry of figure. It is obvious, too, from the account given by the same observer*, that a very complex social system has developed itself among this people, and that they have made considerable progress in the arts of life, although this has hitherto been only turned to account in furthering the traffic in slaves, of which Dahomey is now the centre, so far as the Slave Coast is concerned. The highest civilization, and the greatest improvement in physical characters, are to be found in those nations which have adopted the Mohammedan religion. This was introduced, three or four centuries since, into the eastern portion of Central Africa; and it appears that the same people who were then existing in the savage condition still exhibited by the pagan nations further south, have now adopted many of the arts and institutions of civilised society, subjecting themselves to governments, practising agriculture, and dwelling in towns of considerable extent, some containing even as many as 30,000 inhabitants — a circumstance which implies a considerable advancement in industry, and in the resources of subsistence. The languages of the Negro nations, so far as they are known, seem to belong to one group; although there is a great difficulty in becoming acquainted with them; in consequence of the entire deficiency of written records. The same cause would of course give a want of fixity to their vocabulary: and thus the dialects of two nations descended from a common original, would be likely soon to diverge from each other. Still they all present, so far as is known, the same grade of development, and the same grammatical forms; and various proofs of their affinity with the Semitic tongues have been developed, these being derived from similarity alike of roots and of construction. The Semitic affinity of the Negro nations is further indicated in a very remarkable manner, by the existence of a variety of superstitions and usages among the Negroes of the Western Coast, which prevail also among the Nilotic races whose Semitic relations are most clear, as well as among branches of the Semitic stock itself; this is especially the case with the rite of circumcision, which seems to be universally practised throughout the Negro area.

The southern portion of the African continent is inhabited by a group of nations which speak various dialects of the Kaffre tongue, and which recede more or less decidedly from the Negro type in physical characters. Our acquaintance with them, however, is at present very limited; the interior of South Africa having been as yet scarcely at all explored by civilised man; and the only people well known to us being those of a few points on the coast, such as Kongo on one side, and Mozambique on the other; and those of the southernmost extremity, or the region of the Cape. As we pass southwards from the equatorial region, we find a gradual softening down of the proper Negro characters; and this is greater according to the degree of civilization, and the general improvement in external conditions. Thus, in the people of Kongo (*fig.* 832), and in those of Mozambique and its neighbourhood (*figs.* 833, 834), although the hair is woolly and the colour black, yet the skulls are more vaulted (*fig.* 833) and capacious anteriorly, and have much less of the prognathous character; the nose is much more prominent, the lips are less thick, and the general expression is milder and more intellectual, than that of the natives of Guinea. When we arrive at the true Kaffres, the race of warlike nomadic people which inhabits the eastern parts of South Africa to the northward of the Hottentots, so great a departure from the Negro type presents itself, that many travellers have

* Dahomey and the Dahomans, 1851.

Fig. 832.

Woman of Kongo. (After Rugendas.)

regarded them as having had a different origin. The degree of this departure, however, varies greatly in the different tribes; for while some of them are black, woolly-headed, decidedly prognathous (*fig.* 835), and obviously approaching the modified Negroes of Kongo in

Fig. 833.

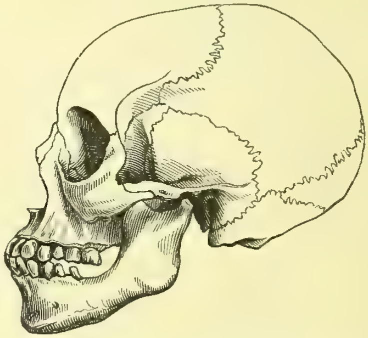
Man from Mozambique. (After Rugendas.)

their features and general aspect, others recede considerably both in complexion, features, and form of head from the typical prognathous races, presenting a light brown colour, high forehead, prominent nose, and tall robust stature. The thick lips and frizzled hair are generally retained, however; but the hair is sometimes of a reddish colour, and becomes flowing; and the features may present a European (*fig.* 836) cast. Even among the tribes which depart most widely from the Negro-type, individuals are found who present a return to it; and it is interesting to remark,

Fig. 834.

Woman of the Mongalla tribe—near Mozambique. (After Rugendas.)

Fig. 835.



Skull of Kaffre. (From a specimen in the Museum of the Royal College of Surgeons.)

Fig. 836.

Kaffre of the Amakosah tribe. (From a portrait by Daniels.)

that the people of Delagoa Bay, though of the Kaffre race, as indicated by their language, being degraded by subjugation, approach the people of Guinea in their physical characters. Generally speaking, the Kaffres are a people very superior in vigour and capacity to the destitute savages who occupy the insulated regions of Negroland, and how a considerable advance in civilization; but between the most elevated Kaffre and the most degraded Negro, every possible gradation is presented to us, as we pass northwards and westwards from Kaffraria towards the Guinea coast, so that no line of distinction between them can be founded on physical characters. So, on the eastern side, we pass up until we meet with the same transition. The languages of these people are distinguished by a set of remarkable characters, which have been considered as isolating them from other African tongues. According to Dr. Latham, however, these peculiarities are not so far without precedent elsewhere, as to establish the very decided line of demarcation which some have attempted to draw; and may be regarded, in fact, as resulting from the fuller development of tendencies, which manifest themselves in other African languages.

The *Hottentot* race (including the Bushman) has, perhaps, so far as regards its physical characters, a better title to be considered as forming a distinct species of the genus *Homo* than any other; for not only do these characters present a combination which is not found elsewhere, but that transitional gradation is wanting, which usually presents itself wherever there is a continuous population that has long occupied the same locality. The peculiarities of these people have been already noticed separately; the following is a general summary of them. The cranium is Mongoliform and brachycephalic, the cheek-bones prominent, the jaws somewhat projecting, the eyes oblique, the nose broad and flat, the lips thick, the chin long and pointed; the complexion is a mixture of black with yellow ochre; the hair grows in little tufts; the stature is low, and the limbs are slight; the buttocks, however, frequently present a steatomatous accumulation. In their cranial characters there is, therefore, an admixture of the Mongolian and the Negro, the former being predominant; and this resemblance to the people of High Asia is the more remarkable, when it is considered that the physical conditions of the Hottentot country bear a very close correspondence with those of High Asia, the habitation of this people being for the most part on *karroos*, or elevated terraces and table-lands, over which the vision extends with as piercing a gaze as that of the Mongols. The buttock-hump, or steatopyga, is not by any means so characteristic of this race as has been imagined; for, as Mr. Burchell has ascertained, it is only an individual peculiarity, about as frequent as corpulence among European nations; and it has been met with in other tribes of Southern Africa, as the Makuani of the Mozambique coast. It cannot, therefore, be regarded as affording the least indication of difference of race, but would seem to result from the operation of the same local influences, whatever may be their nature, as produce a similar accumulation of fat in the rumps and tails of the sheep inhabiting the same regions. The peculiar relation of the Bushman tribe to the Hottentot race, has been already explained; among this degraded people, the same general features present themselves as those which have been described as characteristic of the Hottentots (*figs.* 837, 838.), but in stature, vigour, and capacity, they are much inferior. A compari-

Fig. 837.

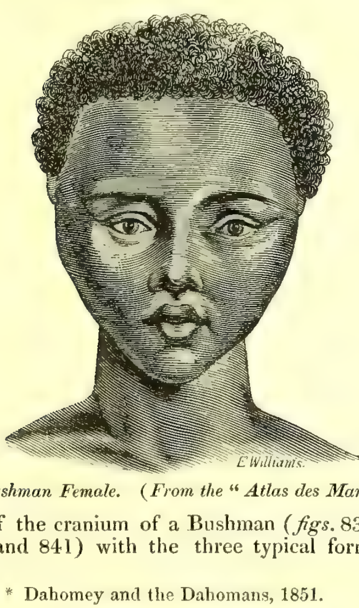


Fig. 838.

Bushman Female. (*From the "Atlas des Mammifères of MM. Fred. Cuvier and Geoff. St. Hilaire.*)

son of the cranium of a Bushman (*figs.* 839, 840, and 841) with the three typical forms already figured, will clearly indicate that the *pyramidal* skull is the one to which this bears the greatest resemblance, especially in the shortness of the antero-posterior diameter, as

* Dahomey and the Dahomans, 1851.

Fig. 839.

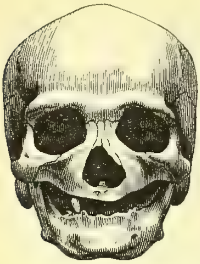


Fig. 840.

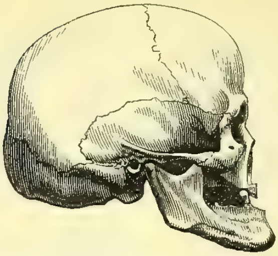


Fig. 841.

Cranium of Bushman. (*From a specimen in the Museum of the Royal College of Surgeons.*)

compared with the parietal, and in the breadth and expansion of the malar bones.

The ethnological position of the Hottentot race is not altogether clear. There is evidence that it once occupied a more extensive area than it does at present, and that this was much encroached on by the Kaffres, previously to the European colonisation of the Cape. This fact lends weight to a suggestion offered by Dr. Latham, in order to account for the abruptness of the transition between the two races : — " Let two divisions of a certain class pass into each other by imperceptible degrees, and let one of the *central* portions of either class spread itself at the expense of the parts belonging to its circumference ; the effect which follows is, that those portions of the area which represent the phenomena of transition are overlaid or overlapped ; and that, instead of two populations coming into contact by imperceptible degrees, they meet as separate classes, with as broad a line of demarcation between their respective representatives, at the peripheries of their respective areas, as there was between their central or typical portions. North-western America illustrates this. The more southern Algonkins have overlaid both the Algonkins of their own section which approached the Esquimaux, and the Esquimaux of the opposite section, which approached the Algonkin. Hence the two populations meet as widely-separated and broadly-distinguished varieties of mankind."* So, it may be surmised, the bold and warlike Kaffres have overspread themselves through a region whose aboriginal population exhibited a transition between the Hottentot and Kaffre types. " The language of the Hottentots," says the same learned ethnologist, " can be shown not to be more different from those of the world in general, than they are from each other;" it has not yet, however, been sufficiently studied to enable its true affinities to be known, though some philologists affirm that it is a degraded Kaffre tongue.†

Passing now to the valley of the Nile, we find a group of nations whose physical characters and languages present a complete and almost uninterrupted gradation from those of the proper African tribes to those of the Semitic group. Under the general designation of *Nilotic* nations may be included the Gallas, the Nubians, the Bishari, and many subordinate groups. These come into close approximation, both locally and physically, with the Eastern Negroes of the first division, and

Fig. 842.

Souakiny Chief,—Eastern Nubia. (*From a portrait given in " Salt's Travels."*)

with the northern Kaffres of the second. The colour of the Gallas varies from a deep black

* Varieties of Mankind, p. 498.

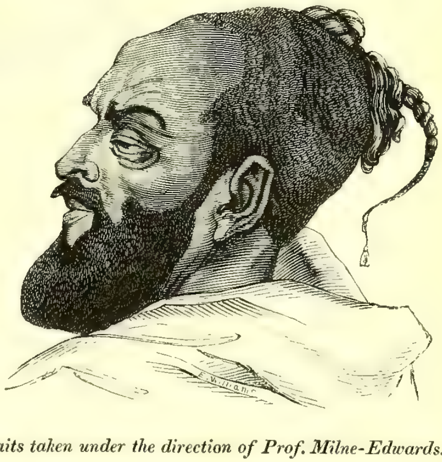
† The author thinks it worth while still to repeat a suggestion which he made some years since; namely, that the Hottentot race is the remnant of an earlier migration from High Asia, than that which was the stock of the great bulk of African nations; and that it has been driven down into the remotest corner of the continent, just as the aboriginal Turanian population of south-western Europe seems to have been driven back by the Indo-European immigration, and at last to have been limited to the Basque provinces. For anything yet known to the contrary, the structure of the Hottentot language may, like their physical conformation, be more closely related to that of the Turanian stock than to the Semitic, with which the languages of Northern Africa are obviously connected.

to a brownish yellow; their stature is tall; their bodies spare, wiry, and muscular; their frontal profile vaulted, their nose straight or even arched, their lips moderately full, their hair often hanging over the neck in long twisted plaits. Nearly the same description applies to some of the Nubian tribes (*fig.* 842), of which the resemblance to the Arab physiognomy becomes very striking, although their colour is jet-black; and, as already shown, there is distinct evidence of their Negro ancestry. The languages of these Nilotic people present an intermediate gradation between the proper Semitic and the proper African; and all that has been made known by the explorations in these regions, which have been carried on, more or less uninterruptedly, ever since the French expedition into Egypt, tends to break down the line of demarcation which was supposed to separate the African nations from all others. To a similar result have tended all those Egyptological researches which have been carried on with so much ardour during the same period. For a careful examination of the delineations of themselves left to us in the paintings and sculptures of the ancient Egyptians, and of the crania preserved in their sepulchres, leaves no reasonable doubt, that in their physiognomy and complexion they were *essentially African;* although very marked varieties in cranial conformation, and in the hue of their surface, appear to have existed amongst them. The Copts, or existing natives of Egypt, seem, on the whole, pretty nearly to represent their physical characters, although in a condition of comparative degradation, owing to the state of subjection to which they have been reduced; and although the existing Coptic language has been undoubtedly changed from its original form by the successive colonizations and conquests to which the country has been subjected, yet it still shows a marked affinity with the proper African languages in certain peculiarities of its construction.

Lastly, the northern and north-western portion of the African continent is occupied by tribes whose Semitic origin is undoubted. Several immigrations appear to have taken place at different times from the Syro-Arabian stock; but that which has most claim to the title of an aboriginal population, is that of which the *Berber* races (from which the north-west of Africa received the designation of Barbary) may be regarded as the types; the Kabyles of Algiers and Tunis (the people of Abd-el-Kader), the Tuaryks of Sahara, and the Shelahs or mountaineers of Southern Morocco, being branches of the same stock; as were also, most probably, the Guanches or ancient population of the Canary Islands. These people all speak dialects of a language, which has been shown by Prof. Newman to be an offset from the Semitic: and whilst the complexion, and even the hair and physiognomy, of those which approach the Negro area, present a remarkable approximation to those characteristic of the Negro, those of the northern and more elevated districts retain the Caucasian type, and some of them are quite fair in skin, and European in feature. But subsequently to the settlement of these tribes in the regions they still inhabit, there have been colonizations by Phœnicians and true Arabs; and these immigrants have for the most part remained distinct from the aboriginal population (*figs.* 843, 844),

Fig. 843.

Fig. 844.



Algerine Arabs of the Mozabite tribe. (*From portraits taken under the direction of Prof. Milne-Edwards.*)

their languages being divergent, and their habits and grade of civilisation different. Such were the sovereignties of Morocco, Algiers, and Tunis, which brought the aboriginal tribes under nominal subjection to themselves. Notwithstanding its Semitic affinities, the language of the North-African aborigines is considered by Dr. Latham as having affinities also with the proper African tongues, and as having been isolated from them without sufficient reason; and if this be the case, another link of transition exists, which, with those previously named, brings the two groups into such relations, that their separation cannot be justified. By Dr. Latham, accordingly, the Syro-Arabian or Semitic race is ranked with the African under the general designation *Atlantidæ*.

IV. American Nations.—The aboriginal inhabitants of America have been considered by some ethnologists as a department of the human family very distinct from the inhabitants of the Old World; and attempts have been frequently made to define them as a race by physical characters. But these attempts have been founded upon a very imperfect acquaintance with the nations peopling this vast continent; for, taken in the aggregate, they are by no means uniform either in physical qualities, in intellectual endowments, moral character, or grade of civilisational development; nor is the line of distinction between them and the rest of mankind nearly so obvious or strongly marked as is usually imagined. Thus the native Americans have been described as "red-men;" but there are tribes equally red, and perhaps more deserving that epithet, in Africa and Polynesia; and the American nations are by no means all of a red or copper hue, some being as fair as many European people, others being brown or yellow, and others nearly, if not quite, as black as the Negroes of Africa. Again, it has been attempted by anatomists to distinguish the American races by a certain configuration of skull and form of features; and even Dr. Morton, in his splendid work entitled "Crania Americana," has given his authority in support of the opinion, that such distinctive characters are to be found "in the squared or rounded head, the flattened and vertical occiput, the high cheek-bones, the ponderous maxillæ, the large quadrangular orbits, and the low receding forehead." Nevertheless, even he is obliged to admit that very considerable diversities present themselves in the cranial conformation of the American nations; and he altogether excludes the Esquimaux, who, according to the evidence of language, must be regarded as being as truly an American people as any other, in spite of their obvious conformity to the Mongolian type of cranial configuration. And it will be observed that many of the characters just enumerated are those of the Mongolian cranium; a decided approximation to which may be seen among several tribes, whose dwelling is much further south than that of the Esquimaux. The testimony of travellers who have visited parts of the continent remote from each other, and who have scrutinized with observant eyes the physiognomy and form of head, not in individuals only, but in nations, is very decided as to the marked varieties in configuration which present themselves among these; thus, says that eminent zoologist, M. D'Orbigny, "A Peruvian is more different from a Patagonian, and a Patagonian from a Guarani, than is a Greek from an Ethiopian or a Mongolian." The accompanying figures present examples of this diversity (*figs.* 845 and 846).

Fig. 845.

Indian of the Oto tribe,—basin of the Mississippi. (*From the "Atlas du Voyage du Prince de Neuwied."*)

Fig. 846.

South American of the Charruan tribe. (*From a portrait by Werner, in the Museum of Paris.*)

Notwithstanding this diversity in their physical characters, however, there is strong evidence that the American nations constitute one natural family, bound together by community of descent. This appears from the remarkable relationship which has been discovered among their languages; not, however, in their words or even their roots, but in their grammatical construction. In regard to vocabulary, indeed, there are few parts of the

Fig. 847.

South American of the Puri tribe,— interior of Brazil. (After Rugendas.)

Fig. 848.

South American of the Achagua tribe,—basin of the Orinoco. (From a portrait by M. Roulin.)

globe in which so many dialects, or even distinct languages, are spoken within such limited areas; and thus, if difference in this respect be considered as a sufficient reason for denying the mutual affinity of the races, the number of separate stocks must be enormously multiplied. On the other hand, the mutual relationship just indicated, which consists more particularly in the very remarkable *agglutination* of words or portions of words, has been found in all the American languages which have been carefully examined, including some of the most important dialects spoken in parts of the continent very remote from each other. And it is easily shown that this practice, carried on without any regular system, but according to the wants and caprices of each detached community, will, in the absence of such a literature as gives fixity to a language, almost necessarily induce such changes, that two offsets of the same stock, developing themselves under different circumstances, shall cease in a few generations to be mutually intelligible. There are other causes, too, in the character of the people themselves, and in the mode in which they employ language, which tend to introduce such variations. Their speech is, for the most part, rather an expression of their own ideas and emotions, than a reflex of external things, — much more *subjective* than *objective;* and hence their names for the most familiar objects, or the simplest ideas, are long compound words or epithets, which are in striking contrast with the brief terms employed for the same purposes by most other nations. This feature in their phraseology seems common to all the American languages; and it is strikingly indicative of a fundamental peculiarity in the psychical character of the people, namely, a predominance of the imaginative and rhetorical disposition, over the mere sensuousness which is observable among most nations that have attained to a similar grade of material progress. Those, indeed, who are most familiar with the psychical nature of the aborigines of America, have been struck with the manifestations they present of greater energy and mental vigour, of a more reflective nature, of greater fortitude, and of more consistent perseverance in their various pursuits and enterprises, than are to be met with among any of the aboriginal nations of the Old World; and these peculiarities are in great part due to the intensity of their selfish emotions, which exhibits itself in the sullen and unsocial character, the proud apathetic endurance, the intensity of hatred and revenge, the feeble influence of the benevolent affections, and the deep malice-concealing dissimulation, which are so remarkable in the dwellers amid the dark solitudes of the American forests. Among many of the American nations, moreover, traces have been observed of ancient institutions, — complicated forms of government, regulated despotisms or monarchies, privileged orders, hierarchical and sacerdotal ordinances, systematic laws (the result of reflection and a settled purpose) connected with marriage, inheritance, family relationships, &c. and other customs, — that mark a very early progress in social development, the *forms* of which are in great degree peculiar to them. Their opinions, moreover, respecting a future state, and the nature and attributes of invisible agents, are strikingly different from those of nations who have never emerged from primitive barbarism. They have had in use, moreover, from time immemorial, cultivated plants and domestic animals, different from those of the Old World; and their earliest traditions refer the knowledge of these to some fabulous person, who descended from the gods, or who suddenly made his appearance among their ancestors; thus indicating the remoteness of the era of their separation from the inhabitants of the Old World, who have similar mythical legends in regard to the introducers of *their* first arts and acquirements.

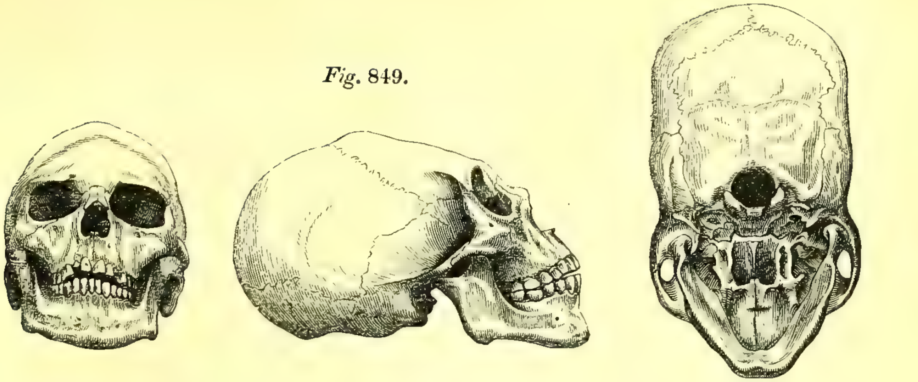
Abundant evidence is afforded, by architectural and other remains still existing, as well as by the accounts of the early Spanish historians, of the high degree of civilisation which some of the nations of America had attained, previously to the European immigration, especially in the warmer regions of that continent. Thus the natives of Mexico had erected stupendous edifices, which rivalled those of Egypt; and although they did not attain to the greatest of human inventions,—that of symbols representing the sounds of words,—they had long aspired after it, and had contrived a method of recording events and of handing down to memory the passages of their ancient history. They had even made great advances in science, and had a solar year with intercalations on the principle of the Roman calendar. They were diligent cultivators of the ground, and also expert miners and workers in metals; even astonishing the workmen of Europe with their skill in setting gems. They appear, too, to have been influenced by a deep sentiment of religion, and to have had a very stately and majestic ceremonial. Nevertheless, they do not seem to have derived from these advances in civilisation, any moral improvement, or any mitigation of that sullen malignity which seems to be the general character of the native tribes of the New World; and their religion was far from having an exalting influence, since their gods had no attribute of clemency or mercy, but were invested with the worst forms of their own dark passions. In Peru, also, we find remains of Cyclopean structures erected during the government of the Incas, which bear comparison with those of ancient Egypt; and the wonder is increased when it is recollected, that no beast of burden save the llama existed in Peru before the Spanish invasion. At a time when there were no public highways in Britain but such as were relics of Roman greatness, there were roads of 1500 miles in length in the empire of Peru, carried over heights which overtop the Peak of Teneriffe. The ancient Peruvians were ignorant of the manner of forming an arch; but they had constructed suspension-bridges over frightful ravines. They had no implements of iron; but they could move blocks of stone as huge as the Sphinxes and Memnons of Egypt.

Everything, then, seems to indicate one of two things; either that the American races are descended from a stock originally distinct from that of any part of the Old World, or that, having had a common origin with the aborigines of Asia and Europe, they have existed as a separate family of nations from a very early period in the history of the race. This question will be considered hereafter; but it must not here be left unnoticed, that several of the tribes of the Western coast of America present a striking physical resemblance to the Peninsular Mongols; and that there are indications of communication between them, at a comparatively late period.*

This brief account of the American races would be incomplete, without a notice of one of their most remarkable customs,—that of altering the form of the skull by artificial compression—which may be traced in different parts, both of the northern and southern divisions of the continent. This flattening was *vertical* in some instances, *horizontal* in others. Of the former, Dr. Morton figures examples, in his "Crania Americana," from the tribe of Natchez Indians (which appears to have been a branch of the Toltecan family) that was exterminated by the French in the year 1730. The compression was effected by means of a bag of sand placed upon the forehead, whilst the occiput lay upon a sort of mould, of which it gradually took the form under the slow but constant influence of this pressure. Some curious bas-reliefs, executed by the Toltecans during their sojourn in Mexico, show that the practice prevailed amongst the most civilised portion of that race. The horizontal flattening is practised at the present time by the Chinooks and other tribes inhabiting the neighbourhood of the Columbia river; the mode in which it is accomplished varying considerably in the different tribes, but the general effect being the same. So highly is this deformity valued by them, that their slaves are not allowed to practise it; and yet the process by which it is induced often gives rise to ulceration of the scalp, and not unfrequently to death. In one of the skulls figured by Dr. Morton, the vertical diameter is reduced to little more than four inches, the top of the cranium presents a flattened arch not far removed from a horizontal plane, and the face is protruded until the facial angle is reduced to 60°, probably the lowest grade ever observed in a human skull; the compression has also destroyed in a remarkable degree the lateral symmetry. Yet the *capacity* of the cranium is not altered by the process; and the "flat-head" Indians are certainly not deficient in any of the mental qualities of their race. Both kinds of flattening appear to have been practised by the ancient Peruvians; in whose sepulchres are found vast numbers of crania, presenting such different degrees of departure from what seems to have been the normal form, that it is not easy to find one which can be positively affirmed to be unaltered. A characteristic example of the effect produced by the process of horizontal flattening is given in *figs.* 849, 850, 851; which represents a skull closely resembling that of a flat-head Indian of the Columbia river. It seems not improbable that the horizontal flattening was practised anteriorly to the advent of the Incas, which may be dated at about the year 1100; and that the vertical flattening was introduced by them. It seems to have been

* See Humboldt's "Views of Nature" (Bohn's edition), pp. 131—133.

Fig. 849.



Artificially-compressed Cranium from Titicaca. (*From a specimen in the Museum of the Royal College of Surgeons.*)

continued among the Peruvians for some time after their conquest by the Spaniards; for the Ecclesiastical Court of Lima passed a decree in the year 1585, forbidding parents, under certain specified penalties, to compress or distort the heads of their children in the various modes which were then in vogue. The practice still exists among certain tribes of South American Indians; and seems to be regarded in much the same light with the artificial compression of the foot by the Chinese, or of the waist by the French and English,—namely, as an artificial development of a natural beauty.

V. Oceanic Nations.—The vast Oceanic area, extending in longitude from Madagascar on the one side, to Easter Island (half way between Asia and America) on the other; and in latitude from Formosa to New Zealand, including the numerous islands of the Indian and Polynesian archipelagoes, and the great island-continent of Australia, is peopled by tribes the greater part of which are undoubtedly related to each other very intimately, and have no near affinities with those of any other region. The only part of the mainland of Asia which is inhabited by an Oceanic tribe, is the Peninsula of Malacca; and there is far more reason to think that this tribe has migrated to that locality from the neighbouring part of Oceania, than that it represents the original stock and line of migration of the Oceanic races. In the physical characters of the Oceanic tribes, two typical varieties present themselves; and these may be designated as the *Malayo-Polynesian*, and the *Negrito*.

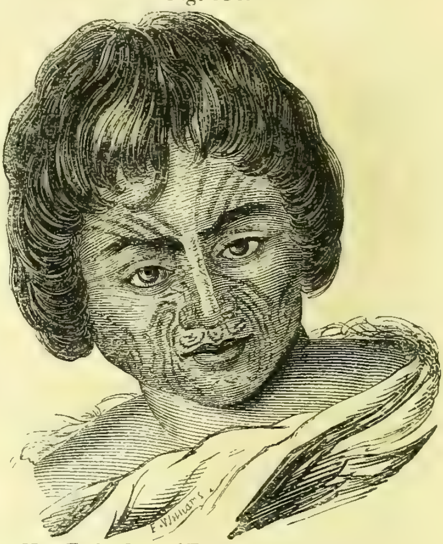
The *Malayo-Polynesians* present a nearer approach to the Mongolian type than to any other; but they must be compared rather with the modified Mongols of the south-east portion of the Asiatic continent, than with the proper Turanian stock. Their complexion is yellow, olive, brunette, or brown, rarely or never darkening into black; their hair, often long, is usually black and straight; the face is usually somewhat flat, the cheek-bones high, and the antero-posterior diameter of the skull short; but there is often a tendency to the prognathous character, such as is shown among the inferior Hindoos. This division of the Oceanic races occupies the greater part of the Indian Archipelago, and the whole of the Polynesian; but it does not exist in New Guinea, Australia, Tasmania, New Ireland, or the islands between it and New Caledonia, which are peopled exclusively by Negritos. That the tribes thus widely dispersed are all descendants of one and the same stock, and belong to the same race, seems distinctly proved by the affinities of their languages; which, although presenting considerable modifications (as might be naturally expected from a prolonged isolation, and from the entire absence of a literature), yet accord, as has been proved by William Humboldt, in many of their primary words, and in their general plan of construction. This mutual relationship is the closest among the Malayan dialects of the Indian Archipelago on the one hand, and among the tongues spoken by the various Polynesian islanders on the other; but these two groups are also undoubtedly related to one another, in such a manner as to constitute but one family of languages.—The proper *Malays* are, for the most part, a people of short and slender stature, and small limbs, but well-formed and vigorous; they have flat faces, somewhat oblique eyes, and features resembling the Chinese; the hue of their complexion, however, is considerably deeper, but is not so dark as that of the Hindoos, yellow being still a large ingredient. These characters, however, are far from being uniformly exhibited by the whole Malayan branch; and in particular it is to be remarked that a tendency to the prognathous type occasionally shows itself, as in the skull of a Bugis of Celebes, described by Blumenbach.—Between the Malayan and the proper Polynesian area is a small group, including the Pelew, Caroline, and Marianne islands, the inhabitants of which are even more conformable to the Mongolian type than are either the true Malays or the proper Polynesians; these are termed by Dr. Prichard, *Micronesians*. A consideration of the probable lines of that migration which must be admitted to have taken place, unless every island is supposed to have had its own independent stock, has led Dr. Latham to the conclusion that the Micronesian group was peopled before the Polynesian area. — The proper *Polynesian* branch presents such a wide diversity in physical characters, that if it were not for the unquestionable community of language, usages, &c., it might be thought to consist of several races, as distinct from each other as they are from the Malayan branch. Thus the Tahitians and Marquesans are tall and well made; their figures combine grace and vigour; the skulls are usually as symmetrical as those of most Europeans; and their physiognomy presents much of the European cast, there being only a slight flattening of the nose, expansion of the nostrils, and thickening of the lips, to indicate a degradation, which is rather in the Negro than in the Mongolian direction (*fig.* 850.). The com-

Fig. 850.

Tahitian Female. (*From a portrait by an officer of "L'Artemise."*)

plexion, especially in the females of the higher classes, who are sheltered from the wind and sun, is of a clear olive, or brunette, such as is common among the natives of Southern Europe; and the hair, though generally black, is sometimes brown or auburn, or even red or flaxen. Among other tribes, as the Sandwich Islanders, the New Zealanders, and the Tonga and Friendly islanders, there are greater diversities of hue and conformation (*fig.* 851.); some being of a copper-brown colour; others, nearly black; others, olive; and others, almost white; the fairer races are generally taller and more vigorous, whilst the darker are inferior in stature and figure. Many of these varieties present themselves in a single community,

Fig. 851.



New Zealander. (*From a portrait by Earle.*)

such as that of New Zealand, and are so strongly marked as to have led to the idea that the difference is due to an intermixture of races; but the unity of language, and the absence of any other indication, prevent such a supposition from possessing the least claim to reception. It is a most remarkable fact that the *Madecassians*, or natives of Madagascar, speak a language which is obviously derived from the Malayan stock, being most nearly allied to that of the Philippine Islands; and some of the multiform population of that island bear a striking resemblance to Malays, whilst others seem more allied (as might be expected) to the African nations of the mainland. At present, the character and origin of the Madecassian population is one of the doubtful questions of ethnology.

The *Negrito* race presents a marked approximation to the physical characters of the true Negro. The skull is of the prognathous type; the nose is flattened, the nostrils expanded laterally, the lips thickened, and the complexion a deep brown, or even black. The character of the hair varies considerably; for in some cases it is long and straight (*fig.* 827.); and in others, crisp and frizzly; and in others, even woolly (*figs.* 805, 806.). By Dr. Prichard and others a distinction was drawn between those with straight, and those with woolly hair; but the validity of this can scarcely be maintained, since it appears that the very same people may present one or the other kind of hair, according, as it would seem, to the climatic and other conditions under which they exist. The Negrito race not only inhabits the area which is more exclusively its own, but is also believed to exist in the interior of many of the larger islands of the Indian Archipelago; it is not always certain, however, whether the people whose presence there is reported, are Negritoes or dark

Fig. 852.

Portrait of Ourou-Mare, an Australian Chief. (*From the* "*Atlas du Voyage au Terres Australes.*")

Malays. There are many indications, indeed that the Malayo-Polynesian and Negrito races are not really so distinct, as the marked dissimilarity of their respective physical types, and the complete want of conformity between their languages, would make it appear. For as, on the one hand, some of the subdivisions of the former present a decided tendency towards the prognathous character, and the depth of complexion, which are typical of the latter, so among the latter we do find a lighter shade of skin, a greater symmetry of skull, and a considerable improvement in form and feature, not unfrequently displaying themselves; as is the case, for example, with some of the Papuans, or inhabitants of New Guinea, and even occasionally with the Australian aborigines, notwithstanding that the physiognomy of the latter generally exhibits a very manifest degradation (*fig.* 852.) The relations of the language of the different branches of this race to each other, and to other languages, have not yet been clearly developed. They appear, however, to possess a general community of structure, with differences in the vocabulary; and such differences present themselves very prominently among some of the languages of Australian tribes, whose common origin cannot be questioned. According to Dr. Latham, they contain a considerable infusion of Malay words; but this is scarcely enough to establish their community of origin with the languages of the Malayo-Polynesian stock. Some other affinities have been pointed out by Dr. Prichard; but these, it is remarkable, are not so intimate as those which subsist between the Australian and the Tamulian of Southern India. Remote as the connection seems, this circumstance adds weight to the idea, that the native Australians are an offset from that southern branch of the great nomadic stock of Central Asia, which seems early to have spread itself through the Indian and Indo-Chinese peninsula.

It is commonly believed that there is no people, excepting the most degraded of the Negroes and the Bushmen of the Cape, whose physical condition is so miserable, or whose mental development is so low, as that of the Australian aborigines; but the testimony of those who have visited them in their native haunts, where as yet they have been uncontaminated by contact with Europeans, and have not suffered from the deprivation of the land which affords them the means of subsistence, is very decided in regard to the exaggeration which has prevailed on this point. In particular it may be remarked, that, although they have less susceptibility than exists among many other rude nations to religious impressions, yet it is certain that they are not destitute (as some have represented them to be) of all idea of a God; they even seem to have a notion of a future state, and a belief in good and evil angels. They have likewise a superstitious belief in magicians or sorcerers; a belief which seems to attain its highest point among the nations of High Asia. Many complex and singular institutions, especially relating to the tenure of property, exist among them; to which the nearest approach elsewhere is presented by the North American Indians.

Looking, then, to the great diversity which exists among the subordinate groups of which both these divisions consist, and their tendency to mutual approximation, it cannot be shown that any sufficient reason exists for isolating them from each other; and, as already remarked, there seems no medium between the supposition that each island had its aboriginal pair or pairs, and the doctrine that the whole of Oceania has been peopled from a common stock. Looking, again, to the very marked approximation which is presented by certain Oceanic tribes to the Mongolian type, and this in a locality which, on other grounds, might be regarded as having received the first stream of migration, the possibility, to say the least, can scarcely be denied, that the main-land furnished the original stock, which has undergone various transformations subsequently to its first dispersion; these having been the result of climatic influence and mode of life, and having been chiefly influenced as to degree, by the length of time during which the transforming causes have been in operation. At any rate it may be safely affirmed, that there is no physical peculiarity which entitles the Oceanic races to rank as a group, which must have necessarily had an original stock distinct from that of the continental nations.

General Recapitulation.

On the whole then, the result of the extensive range of inquiries, of which an outline has now been given, may be stated as follows: —

1. The extremest differences from each other, or from a common stock, presented by the races of Mankind, in regard alike to physical, physiological, and psychological peculiarities, are not greater in degree than those which are known to arise amongst other species of animals possessed of a similar adaptive capacity, under the influence of changes in external conditions; and they differ *only* in degree, not in kind, from those of whose origin in a change of external conditions, in the case of mankind, we have adequate evidence.

2. In whatever mode the types of the principal varieties are selected, they are found to be connected by intermediate or transitional gradations; the descendants of each principal stock exhibiting, in a greater or less degree, a capability of approximation to the characters of others.

3. There is nothing in these diversities, therefore, to justify the erection of specific distinctions among the different races of Mankind; and, whilst a probability of the *unity* of their original stock may consequently be said to exist, all scientific evidence points to the conclusion, that, if the original stocks were multiple, they must have had attributes essentially the same.

4. The supposition of a number of distinct "protoplasts," one for each principal region of the globe, is not required to account for the extension of the human family over its area, and it does not afford any assistance in accounting for the phenomena of their existing distribution; since each principal geographical area contains races of very diversified physical characters, the affinity of whose languages makes it next to certain that they must have had a common descent.

5. The evidence of philological research decidedly tends to the conclusion, that such affinities exist between the earliest known stocks of the principal groups of languages now and heretofore in use, as can only be reasonably accounted for on the hypothesis of their common origin, and the consequent radiation of the whole species from one centre. What that centre is likely to have been, is a legitimate object of inquiry; and the following, which have long been regarded by the author as the most probable deductions from modern Ethnographical research in relation to this subject, are now submitted with additional confidence, on account of the confirmation which they have received from the most recent investigations, and, in particular, from their conformity with the arrangement which Dr. Latham's linguistic researches have led him to adopt.

The stock from which the globe was originally peopled, is probably more nearly represented at this time by the Turanians of High Asia than by any other; and some part of that region was probably their primary seat. It is among the Mongols and their allies, that that combination of physical attributes which is best adapted to the exigencies of a nomadic life, and that constitution which renders a nomadic life a necessity of their nature, most characteristically present themselves. The bodily system of these people possesses a vigour and adaptiveness, which enables it to flourish under all the diversities of climate to which their wandering propensities conduct them; and they can accommodate their mode of life, without any great departure from their characteristic nomadism, to a great variety of external circumstances. Moreover, the geographical relations of High Asia make it the most central spot on the whole globe, for the radiation of Man to every corner of the habitable world; its connections with all other lands are such as are possessed by no other region; while its climate is so intermediate between that of the frigid and that of the torrid zones, that the passage into either is without any violent transition; and, as a matter of fact, we find that, while the Tungusians and Ugrians have carried the Turanian stock to the shores of the Polar Sea, a Tartar tribe has made itself master of China, and governs the whole of the south-east of Asia, even to the Indian Ocean. This *à priori* argument, however, would be worth very little, if we did not find it in correspondence with the very curious fact, that the most ancient inhabitants of nearly every part of the globe are connected with the nations of High Asia, more or less closely, by affinity of language or of physical characters. This we have seen to be the case, not merely with the Seriform stock of Southern Asia and the Hyperborean and Peninsular Mongols of the north and north-east, but also with the aboriginal people of Northern and Southern Europe, with those of the Caucasus, and with the first settlers of the Indian Archipelago. Not less complete is the transition to the American nations; for whilst, on the one hand, the Esquimaux forms the link of connection, agreeing in physical character with the Hyperborean Mongols, and in language with the mass of the proper American nations, increased acquaintance with the languages of the latter, and with the languages of the Northern Asiatics, has confirmed the suggestion long since made, that they are constructed upon a plan essentially the same; the tendency to agglutination, which is less manifested in the more immediate descendants of the parent-stock, being most fully carried out in its offsets, the Euskarian of the Basque provinces, the languages of the Peninsular Mongolidæ, and the American tongues. The only region regarding which there is not the same amount of evidence, is Africa. But we have seen reason to regard the whole group of African nations as connected, through the Semitic stock, with the Asiatic races; and all the knowledge recently acquired of the language of Ancient Egypt*, together with all the information gained by Major Rawlinson and

* See the memoir by the Chevalier Bunsen, "On the results of the recent Egyptian Researches in reference to Asiatic and African Ethnology, and the Classification of Languages," in the Reports of the British Association for 1847.

other decipherers of the most ancient inscriptions in the south-west of Asia, tends towards the conclusion, that the languages of the African nations are derived from the same fundamental stock with those of the Arian and Turanian, the separation having taken place when they were as yet in that early stage of development, which has remained stereotyped (so to speak) in the Chinese and other Seriform tongues. Looking at the African population under this aspect, we may fairly imagine it to have been first derived from immigrants by no means remote from the Turanian stock; these gradually spreading themselves over the entire continent, became gradually modified in their physical characters by the new circumstances in which they found themselves; and whilst the dwellers in the Nile valley advanced in civilization and in intellectual development, and became assimilated in cranial characters to the other races surrounding the Mediterranean sea, those of Central, Western, and Southern Africa underwent a degradation into the prognathous type, similar to that which has affected the earlier settlers in Oceania, and to which some approach is seen in Southern India. Viewed under this aspect, the re-appearance of the Mongolian type of conformation among the Hottentots of Southern Africa is extremely significant; for, although they are Africans by immediate descent, yet the characters of their remoter ancestry reappear, so soon as a correspondence in physical conditions favours their reproduction.

In certain spots of the globe thus peopled with races derived from a common centre, varieties in physical conformation appear to have sprung up, which, in a scanty and scattered population, would have a far greater tendency to perpetuation than is now anywhere exhibited (see p. 1312); new and more refined languages were originated; local developments of higher forms of civilization occurred; and subordinate centres were thus formed, from which more limited radiations have subsequently taken place, impressing their own features of civilization upon the countries through which they have spread. Thus we have, at a very early period, indications of the Egyptian, the Syro-Arabian, the Arian, the Indo-Chinese, the Mexican, and the Peruvian races, preserved to us in their architectural remains, or in their written records; and although some of these may possibly have been mutually connected at their origin, yet they seem to have been very early separated, and to have attained their fullest development independently of each other. The subsequent migrations of certain of these races, or of offsets from them, have entirely changed their original distribution. The Arab race has extended itself through Northern and even Central Africa, over Southern Asia, and even into the Indian Archipelago. But the Arian has displaced the aboriginal population from almost every part of Europe, and has there formed a secondary centre of radiation, whilst its original stock has been almost obliterated. It is obviously a stock which attains its fullest development under the influence of a moderate temperature; and only, therefore, when it exchanged its original seat for the more favourable influences of European climate, did it manifest its remarkable capabilities. It can scarcely be doubted that from this race, or from a mixed race developed between it and their aboriginal populations, America and Oceania are destined to be re-peopled; the destiny of Asia and Africa, however, seems more obscure. In the former country, the primitive races possess a considerable amount of self-sustaining vigour; and in the latter, they exhibit an adaptiveness to its peculiarities of climate, which will perhaps never be acquired by Europeans. Moreover, whilst the American and Oceanic races appear doomed to extinction as pure races, wherever they come into contact with Europeans, there is no evidence that such is the case with those of Mongolian or of African descent; the latter, indeed, hold their ground with remarkable tenacity, and we may not improbably regard them as destined, under the influence of Christian civilization, to bear an important part in the future history of Mankind. (See p. 1344.)

Addendum.—[Since the former part of this article has been in print, the statements of Count Strzelecki, cited in p. 1341, have been pointedly contradicted, as regards the aboriginal females of Australia, by Dr. T. R. H. Thompson (surgeon, R.N.), who states as the result of personal inquiries among several different tribes, that for a native female to bear children to a native male, after having borne half-caste children to an European father, is by no means an uncommon occurrence. He admits that wherever European settlers are commingled with the aborigines in Australia, the native race disappears. This however, he maintains, does not arise from "any deviation of nature's laws;" but because the European, wherever he takes with him his civilization, takes with him his vices also; so that drunkenness and syphilitic diseases, which soon become rife among the neighbouring population, speedily cause their decline. Dr. Brown allows that the diminution is partly caused by the comparative infecundity of the females who have cohabited with Europeans; but he accounts for this by attributing it to the change of life to which she is subjected.

"From living in a state of nature, with irregular and uncertain diet, exposed to every vicissitude of climate, with no other protection than a few kangaroo skins, or a roll of bark, or of the 'tulka,' she enters on a more regular life, partakes of regular meals, and sleeps no longer exposed. But even with this alteration for the better, she does not bear to the white man more prolifically than to her native husband; on the contrary, her fecundity appears to decrease,—for, on partaking of the white man's comforts, she is a recipient of his vices; she passes much of her time in a half inebriated state, smoking tobacco and drinking ardent spirits whenever they can be procured. Indeed, it is well known, that among the chief inducements for the native female to remain with a European, are the rum and tobacco with which she is supplied *ad libitum*. Can we then wonder, if, after some years spent in a manner which must militate against her capabilities for procreating, more than her previous rude mode of life, she returns to her tribe with a broken constitution, and probably past the usual term of life for conception (they seldom bear children after thirty years of age) to prove in such instances sterile?"*

The same explanation is probably applicable to the case of the other Aboriginal races adverted to by Count Strzelecki; and, if it be the correct representation of facts, it altogether destroys the force of any argument which might be raised upon the infertility of the native females after having borne children to Europeans, in favour of the specific difference of the races.]

Bibliography.—For the facts of the latter part of this article, the author has relied in great part on the learned and elaborate treatises of *Dr. Prichard*, whose "Researches into the Physical History of Mankind" (3rd edit., London, 1836-1847), will long hold its rank as a most complete and masterly treatise on Ethnology. His smaller work, "The Natural History of Man" (London, 1848), though chiefly an abridgement of the preceding, contains in its supplement some additional information of value. The author has also derived much assistance from *Dr. Latham's* more recent treatise, "Natural History of the Varieties of Man," (London, 1850). A large part of the materials of the earlier portion of the article, however, have been drawn direct from original sources.

The Bibliography of the subject, to be complete, must include a most extensive catalogue, not only of special treatises in various departments of Ethnology, but also of Voyages and Travels, and of Philological works and memoirs. The following are selected as having the greatest claims to particular mention:—*Abel-Rémusat*, Recherches sur les Langues Tartares, Paris, 1820. *Adelung*, Mithridates, oder allgemeine Sprachenkunde, Berlin, 1806—1817. *Balbi*, Atlas Ethnologique, Paris, 1826. *Barrow*, Travels in the interior of South Africa, London, 1801—1804. *Beechey*, Voyage to the Pacific Ocean and Behring's Straits, London, 1831. *Bennett*, Wanderings in New South Wales, &c., London, 1834. *Blumenbach*, Institutiones Physiologicæ, Göttingen, 1787. De Generis humani Varietate Nativa, Göttingen, 1795. 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VEIN (Φλέψ, Gr.; *Vena*, Lat.; *Veine*, Fr.; *Blutader*, Ger.; *Vena*, Ital.; *Vena*, Span.). — In general anatomy the term *vein*, in the higher animals, includes four sets of blood-vessels, differing in so many respects from each other as to render it difficult to give a general definition which shall include all under one head, either as it regards structure, course, or function: indeed, so unlike are the different systems of veins, that the only remark which can be said to apply to them all is, that they convey blood in a direction towards the heart; in this respect, as well as in their want of uniformity of character, being directly opposed to the arteries.

The four systems of veins are the *systemic*, the *portal*, the *pulmonary*, and certain *veins peculiar to fœtal life* — the ductus venosus and umbilical vein; and it will be found, upon contrasting them, that they differ much from each other, considering that all enjoy the common appellation *vein*. Thus, the systemic veins, which correspond to the branches of the aorta, excepting those of the abdominal viscera, collect the blood from small and numerous vessels into larger and fewer in its progress towards the heart, constituting a course of circulation of a truly venous character; while, on the other hand, that portion of the blood, which is conveyed to the abdominal viscera by the branches of the abdominal aorta, is first collected from numerous branches into one vessel — the vena porta — thus far the circulation being venous, and is then again broken up into smaller and redividing vessels, after the manner of arteries, and forming, as regards this particular, an arterial circulation, though the vessels are nevertheless veins. In both these instances the blood conveyed by the vessels in question has a similar quality, which is characteristic of veins, and is called *venous*; it is blood saturated with carbon. In the two other systems of venous circulation — the pulmonary and umbilical — the current is venous while the fluid is arterial, these vessels being channels by which the blood is returned to the heart after it has left the arterialising organs. Again, as regards the structure and calibre of veins, our definition is necessarily loose; for, while veins are, in a general way, thin, less elastic, and distensible, as contrasted with arteries, they are nevertheless very varied in these particulars in different regions, and though, for the most part, the calibre of veins is greater than that of the corresponding arteries, still this is not always the case, as is found upon contrasting the area of sections of the pulmonary arteries and veins. It is therefore impossible to give a succinct, and, at the same time, a comprehensive definition of *vein*; and the one which appears to me to be most applicable and to include the members of each venous system is this — *that a vein is a blood-vessel, neither artery nor capillary, conveying blood in a direction towards the heart, having walls of greater tenuity and extensibility and, at the same time, less elasticity than an artery.*

The *literary history* of this subject is chiefly interesting as referring to veins, in their relation to the general circulation. Until the time of Harvey's great discovery, the general physiological relationship of the veins was not understood, and the most discrepant notions were entertained.

Hippocrates, in none of his writings, draws distinction between arteries and veins. *Plato*, in his Timæus, describes the veins as connected with the heart, and receiving blood from it. He regards the veins as the messengers, transmitting to the whole body the orders coming from the soul: he attributes to them the functions of sentient and motor nerves. He considers that the veins have two centres — the heart and the liver; and he makes no distinction between them and arteries. *Praxagoras* taught that the veins were blood-vessels, in contradistinction to the arteries which he considered air-vessels. *Aristotle* drew no distinction between arteries and veins. *Herophilus* describes both arteries and veins as blood-vessels: but he expresses himself in doubt, as to whether the veins arise from the heart or the liver. *Erasistratus*, holding the same general doctrines as *Praxagoras*, further described the texture of veins very minutely, and, according to Marx, he noticed the existence of valves. *Celsus* and *Aretæus* made no advance in this subject. *Galen* distinguished between arteries and veins — both blood-vessels: he also observed the anastomoses of each: he stated the origin of veins to be from the liver, and of the arteries from the heart, and that both were destitute of sensation. *Avicenna* described the veins "venæ quietæ," in contradistinction to the arteries, which he styled "venæ pulsantes et audaces." According to Baulinus, Avicenna described the valves of veins under the name of "*cellulæ*."

The European anatomists of the 15th, 16th and the early part of the 17th century, remained in a state of great confusion and ignorance, as to the bearing of the veins upon the circulating system. *Vesalius* endeavoured to establish the doctrine, that the vena cava takes its origin from the heart, and not the liver; but in this he was opposed by *Sylvius, Columbus, Eustachius,* and *Fallopius.*

While *Cæsalpinus* had occasional faint glimmerings of the physiology of the veins, and *Fabricius,* a remarkable knowledge of their anatomy, it was still left to *Harvey* to indicate their function and relation to the general circulation.*

Veins are the necessary companions of arteries, and are consequently found in all animals possessing the latter vessels.

In the following remarks I shall, for the purpose of examining the subject more completely, divide the consideration of *vein* into these heads: —

I. Structure.

II. Physical and vital properties.

III. Origin, course, anastomoses, plexuses, &c.

IV. Function.

V. Development.

My observations will be principally confined to the consideration of these various heads as applied to the veins of mammalia, especially the human subject. The general anatomy of this subject in invertebrate classes has not, as yet, been sufficiently examined, and does not appear to furnish many points for generalisation beyond those supplied in the mere anatomical description given of the venous system in the several invertebrate classes, in the articles specially applied to them.

I. Structure.—There is scarcely any subject in structural anatomy, which has given rise to so many varied and discrepant opinions, and so much contradictory description as the structure of veins; the different writers upon this point having been numerous, and with scarcely any exception, each giving an account in some, and often important, respects, contrary to those who have preceded him. This circumstance may, to a certain extent, be explained by the various observers having examined different veins, in different regions, and in different animals; and it must be remembered that all microscopical observations necessarily differ from those which are made with the scalpel and the naked eye, and are incompatible unless conjoined, compared and interpreted by the same individual; for, as we shall presently find, structures which seem reduced by dissection to their simplest elements, are found, when submitted to the microscope, to be compound; this is especially the case as it regards the internal tunic of veins, as displayed by coarse anatomy and the microscope respectively. All the discrepancies, however, which have occurred cannot be settled upon these grounds, and it must be granted that in some instances the writers upon this subject have rather drawn upon their imagination than depended entirely upon anatomical demonstration. These conflicting statements, however, serve to keep before us the fact that there is considerable difference of structure in veins in certain regions.

The early anatomists who devoted their attention to the investigation of the intimate structure of organs, applied themselves to the study of the minute texture of veins, and it was indeed one point in their structure which was greatly instrumental in leading Harvey in his discoveries of the circulation.

Constantinus first described the structure of veins as consisting of a "tunica villosa." *Vesalius* speaks of the membranous character of veins, and of their being composed of three sets of fibres, — a longitudinal, a circular, and an oblique. *Fallopius* and *Bartholini* deny the fibrous nature of the coats of veins, and *Diemebroeck* described veins as consisting of one membranous tunic, and believes the statement of the existence of three tunics to be mere imagination. *Willis, Nicolai,* and *Blancard* describe veins as being composed of four coats or tunics. *Haller* denies the existence of transverse muscular fibres in the coats of veins, which had been repeatedly mentioned by other anatomists. *Lieutaud* states that the veins are identical in structure with the arteries, but simply attenuated. *Prochaska* does not admit the existence of a fibrous tunic in veins, whilst *Sœmmerring* says it is to be found only in the larger ones. *Meckel, Autenrith,* and *Bichat* deny altogether the circular or transverse coat of veins, and *Senac* says that their tunics are composed simply of longitudinal fibres.

To these might be added a long list of diverse descriptions, which are however of more literary curiosity than anatomical value.

Veins, in the human subject and mammalia, and I believe in vertebrata generally, are membranous cylinders, consisting of various fibrous coats, lined internally by an epithelium. The walls of veins, which are sufficiently thick to admit of coarse dissection, are with care divisible by the scalpel into *three* layers, an *internal, middle,* and *external* coat: but, when submitted to microscopical scrutiny a still further analysis is made; the internal layer is found to have a compound character, and the direction of the elementary fibres of the several tunics is also shown; the internal and external coats are seen to be *longitudinal,* while the middle is compound, partly *circular* and partly *longitudinal.*

The relation of coarse and microscopical anatomy will be best seen by the following table:

Coarse Dissection.	*Microscopical Examination.*
Internal coat	Epithelium. Fenestrated membrane. Longitudinal fibres.
Middle coat	Circular and longitudinal fibres intermixed. Muscle.
External coat	Longitudinal fibres; compact areolar tissue.

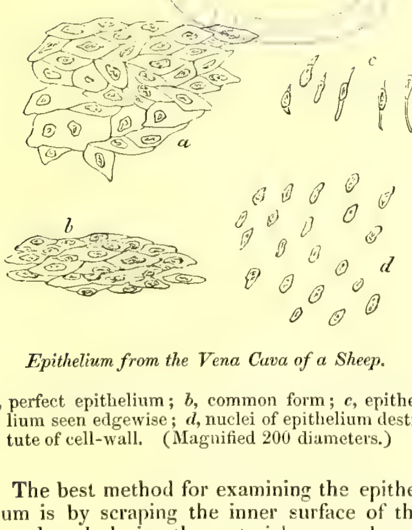
* For more elaborate details of *literary history,* I would refer the reader to the article Circulation, and to the learned "Diatribe Anatomico-physiologica de structura et vita venarum," by Marx. See Bibliography.

This may be taken as a tabular view of the typical structure of veins of larger size, and in the smaller vessels the same order of parts is represented, but with less distinctness and greater tenuity. There are certain regions, however, where the venous texture, both in quality and order, departs considerably from the typical arrangement: these will be noticed hereafter.

In the following observations, the several coats of the veins will be described in succession, beginning with the innermost.

Epithelium. — It is difficult (as has been observed by *Henlé*), in all cases, to make out a distinct epithelial layer lining the vascular cavity; but, as far as my observations go, it is more constant in arteries than in veins, and the epithelium is more perfectly formed in the former than in the latter. The anatomist will frequently make search in vain for epithelium on the inner surface of veins, and, when found, a perfect epithelial cell is less common than one imperfectly formed, the nucleus existing, but the cell-wall either partially or wholly absent.

Fig. 853.



Epithelium from the Vena Cava of a Sheep.

a, perfect epithelium; *b*, common form; *c*, epithelium seen edgewise; *d*, nuclei of epithelium destitute of cell-wall. (Magnified 200 diameters.)

The best method for examining the epithelium is by scraping the inner surface of the vessel, and placing the material removed on a slip of glass; or by viewing the free edge of a valve under the microscope. Existing in its most perfect form the epithelium is of a diamond or rhomboidal figure, containing a nucleus, large in proportion to the cell, of a granular character, and lenticular or oval form. The nucleus is distinct and well defined. The cell itself is clear, pale, and watery to an extent that it is impossible to portray in a woodcut. Henlé states that the long axis of the rhomboid corresponds with that of the vessel in which it exists. In the figure (*fig.* 853. *a*), is represented the most perfectly formed specimen I have seen from a vein; the rhomboidal figure being very marked: it was obtained from the vena cava of a sheep. There is also seen (*fig.* 853. *b*), a more common form, where the cell and nucleus are both present, but the structure is less regular and more confused. The epithelium is of the pavement or scaly form, existing in a single layer: the cells are flat, and either have no cavity, the opposed sides being adherent, or the cavity is very minute. This is displayed in the drawing (*fig.* 853. *c*), where some cells are seen edgewise: in this position the dimensions of the nucleus are observed to bulge out the cell-walls where it is placed, while the cell itself forms a comparatively narrow line, or is even reduced in appearance to a mere linear filament attached to the nucleus, sometimes at one extremity and sometimes at both.

But the condition in which I have most commonly found the epithelium is that represented at *d* in the accompanying figure; the nucleus, the essential part of the cell, being apparently all that is present, and representing the whole epithelial structure. These lenticular corpuscles, the nuclei, are scattered on the inner surface of the vein in pretty much the same position and form as if the cells were present, but the cell-walls are not sketched out, or the nuclei are only here and there partially invested by a cell. This appearance I have observed in the freshest specimens, and it may also be produced by keeping those where the cell is distinct for a short time, when the cell-wall liquefies, and becomes invisible. From the fact that the nuclei are in some instances pretty equally separated from each other, and hold about the same relative distances, whether the cell-wall be present or not, it would seem not improbable that, where not visible, the cell might still exist in a state of imperfect and indistinct formation, — that the blastema may be present in a mucilaginous condition, but of sufficient density to retain the nuclei in their proper relative position.

The nuclei may sometimes be seen thus arranged on the surface of a valve near its clear, thin edge, as is seen with unusual distinctness in *fig.* 865. A. These appearances are generally destroyed by manipulation. When a valve is placed for examination, the nuclei are apt to float off its surface in the fluid with which the object is moistened, and arrange themselves along the free margin of the valve in the interval between its edge and the glasses.

Henlé has represented, in his matchless work on general anatomy, the edge of a valve magnified, in which the nuclei of epithelium are arranged on a clear area, which rims the margin of the valve; and this transparent, structureless boundary he describes as the epithelial cells, in which the nuclei, also visible, are embedded. I have seen well developed epithelium at the edge of a valve, but it did not present the appearance depicted by Henlé, the cell being a mere line as represented in *fig.* 865. A. *a*, and scarcely forming a transparent edge. I have also occasionally seen a structureless rim to a valve, and as that was not changed by the washing and brushing off of the superimposed epithelium, I have given it a different interpretation: I have indeed considered it as a reduplication of the fenestrated membrane, existing there in a state of great tenuity and destitute of fibrous striations.

From the vena cava of the human subject I have obtained epithelium, differing far from the normal form. The specimen consisted of flat, irregular cells, with a small bright nucleus; some cells distinct, others pale and ill defined; some densely granular, others scarcely so at all.

In *Birds* (Loon — *Colymbus septentrionalis*), I have seen the epithelium diamond-shaped, with a large, flat, bright nucleus.

In *Batrachia* (Frog — *Rana temporaria*), the epithelium was large, pale, and irregular.

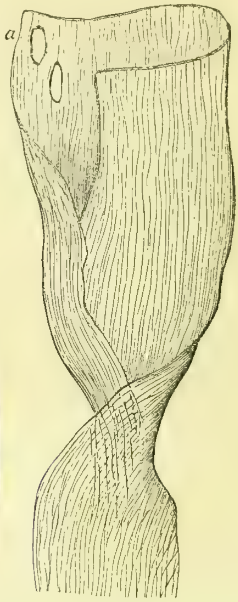
In *Fish* (Cod — *Gadus morrhua*) the epithelium was large, irregular, and granular.

Fenestrated membrane. — This structure, which Henlé has called the "fenestrated," or "striated" membrane, is placed intermediately between the epithelium and the fibro-vascular elements of the vessels' walls, and, from this circumstance, as well as its physical properties, it bears a strong resemblance to the basement or limitary membranes on the skin, the serous and mucous surfaces.

This structure has been described and figured by Henlé, in a manner which exactly coincides with my own observations. When a portion of the membrane is stripped off the inner surface of a vein (or artery, for it is the same in either), and examined under the microscope, it is found to consist of a thin, continuous sheet, of a pellucid, structureless membrane, to which are adherent some reticulated fibres, having a longitudinal direction — hence it is "striated." It is also frequently perforated with small holes, from which circumstance it is called "fenestrated." This homogeneous membrane has the remarkable property of rolling itself up in the form of a scroll, somewhat like the elastic laminæ of the cornea. According to Henlé, it rolls itself in the longitudinal direction, but I have found the same tendency in the opposite course. The apertures, or fenestræ, seen on the membrane, all have more or less of a circular or oval form, and I have found that the number and extent of these perforations depend on the manipulation it has undergone. Its physical properties are peculiar; it is crisp and somewhat elastic, and its inclination to roll up in a scroll is so great, that it is never seen in a flat form. The elasticity, which it possesses, is the reason, as it seems to me, why the fenestræ are universally of a rounded form; for when any lesion is effected in it, retraction occurs all round from the injury, and thus makes the *point* or *line* of lesion the axis of a *circular* or *oval* aperture, as the case may be. In several specimens of this tissue, in which no fenestræ at first existed, I have produced them to any extent by pricking or lacerating it with needles. The fenestræ in the figure were thus produced.

The longitudinal striations appear to me to be some fibres of the next tunic, — the internal longitudinal fibrous coat — accidentally adherent to the homogeneous membrane.*

Fig. 854.



Fenestrated or Striated Membrane from the Jugular Vein of the Red-throated Diver (Colymbus septentrionalis).

a, Fenestræ. (Magnified about 100 diameters.)

In the accompanying drawing (*fig.* 854.) is represented a portion of this membrane, from the jugular vein of the red-throated diver (*Colymbus septentrionalis*). It was of a pale pink tint, from contact with the blood in the vessel, and, seen by transmitted light in the microscope, had a slight yellow cast. It was marked by fine longitudinal threads on one surface, which projected at some spots beyond the torn edge of the membrane.

Purkinje and Rauschel consider this membrane as similar to the middle coat of arteries. Valentin describes it as a peculiar structureless membrane. Henlé considers it as a transition from epithelium to fibrous tissue, in which opinion he is supported by Schwann.

The fenestrated membrane has been found on various parts of the internal surface of the arteries and veins; but the best specimens I have seen have been from the principal veins of large birds (goose, loon, gull), &c. At the

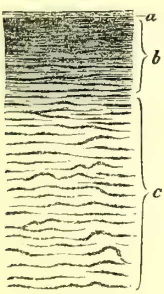
* Henlé has made a singular speculation concerning the nature of this structure: he believes it to be an intermediate stage between the epithelium and the longitudinal fibres next beneath it — that the former is converted into the latter, and that this is its intermediate condition. He believes that the epithelium becomes fused into a continuous sheet, and the nuclei absorbed, and that this subsequently breaks up into fibres, — in short, that fibrous tissue is formed from epithelium, and that the coats of the vessels derive their density and increase from the epithelial cells secreted on their interior.

free margin of valves I have occasionally seen, as noticed above, a clear, structureless rim, which I have imagined to be this membrane reduplicated, the membrane being extremely thin, and the interposd fibrous lamina not reaching quite to the margin.

It is said by Henlé and others only to exist in a few places, and certainly it is not always to be found, though it is not perhaps right to limit its existence to those spots only where it has been recognised, as its extreme tenuity and firm adhesion to the next coat might account for its not being generally seen.*

The tissue in question is best seen by slitting up a vein and pinning it out on cork. The inner surface is then scratched with a needle after it has been moistened. The fenestrated membrane retracts, and its edges may be ruffled up and a small portion removed by the points of very fine forceps, and thus obtained for examination, which is best done without any superimposed glass, as that flattens the coils and folds, and it is impossible to unravel them.

Fig. 855.



Transverse vertical Section of the Wall of the Subclavian Vein of an Ox, exhibiting the relative Thickness of the Three Coats.

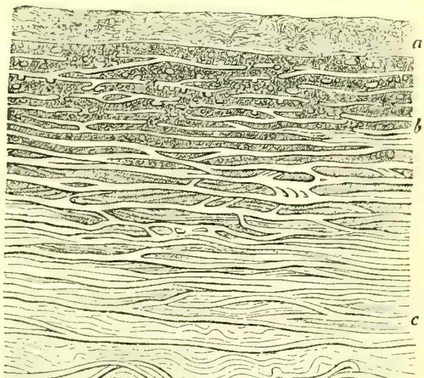
a, internal coat; *b*, middle coat; *c*, the entire external coat. (Magnified 40 diameters.)

Internal tunic of longitudinal fibres. — The internal tunic of longitudinal fibres is extremely thin, and occupies but a very small amount of the thickness of the vessels' walls. This is well seen in *fig.* 855. *a*, which is a transverse section of the subclavian vein of an ox, made vertical to the surface, and displaying the relative thickness of the three elementary fibrous coats.

Specimens for displaying the profile views of the walls of veins are best obtained by slitting up the vessel, pinning it out upon cork, and suffering it to get dry. Sections are then to be made vertical to the surface, either parallel to, or at right angles with, the axis of the vessel. Thin shavings may then be removed with a very flat knife (and for this purpose, a Beer's cornea knife is the best), and when placed on a slip of glass, moistened, and covered with a square of thin glass, are ready for observation. The accompanying drawings were made from sections thus obtained.

When a longitudinal section of the internal tunic is examined with a high power, as in *fig.* 856. *a*, it is seen to consist of very fine yellow elastic tissue, which is peculiarly pale and indistinct, having mainly a longitudinal direction, but being much interlaced and matted together, so that its longitudinal course is, in many situations, obscure. This coat is seen to be fine, and dense, and in strong contrast to all the other structures, from which it is separated by a distinct line of demarcation. When thus viewed, the fibres of this tunic are seen to present a succession of waves, not unlike those of white fibrous tissue, but finer and smaller: whether these undulations are from its own inherent properties, or whether they are produced by its adhesion to the next tunic, whose elastic contraction is greater than its own, thus throwing it into folds and waves, I am unable to say. The identity of these fibres with yellow elastic tissue is shown by the action of acetic acid, which does not destroy them, but renders them even more distinct, while the contiguous

Fig. 856.



Longitudinal vertical Section of Wall of Subclavian Vein of an Ox.

a, internal coat rather thicker than common; *b*, middle coat; *c*, part of external coat. (Magnified 200 diameters.)

* It appears to me that there are sufficient grounds to acknowledge the existence of a limitary membrane beneath the epithelium in the blood-vessels, and no sufficient reason to question its universal distribution. It must be recollected that there are certain regions, even in the mucous membrane (the nasal fossa, for instance), where no basement membrane has been found, and I am not aware that, in the skin, it has ever been separated from the chorion, and yet in neither case is its existence doubted. To exhibit the limitary membrane well, some peculiar mechanical arrangements of the surface is necessary, as papillæ or crypts, and such are not presented on the surface of blood-vessels. It is not to be wondered at, therefore, that there is here great difficulty in displaying the limitary membrane.

masses of white fibrous tissue are obliterated. When treated with this reagent the fibres of this coat lose their wavy character to a certain extent, and present intersecting undulations. (*Fig.* 857. *a.*) When the internal coat is seen in transverse section, it presents a granular, indistinct appearance, without fibres of any determinate direction : in some places it presents lines of a crumpled or corrugated aspect. In *fig.* 858. *a*, this may be seen, as also its distinctness from the next coat, from which it is separated at one part by a slight interval.

This coat appears to exist in all the veins, and in the smaller ones, and larger capillaries when treated with acetic acid, as hereafter to be described, its presence would seem to be indicated by the internal longitudinal nuclei, which are then displayed.

Middle coat of intermixed circular and longitudinal fibres. — This tunic occupies about one-fourth of the entire thickness of the wall of a vein. Its internal boundary is sharp and distinct, where this coat is in contact with the internal, but the outer boundary, where it gradually merges into the external, is indefinite, and indeed artificial.

In *fig.* 856. the middle coat is represented at *b*, and is composed of intermixed fibres of longitudinal and transverse yellow elastic tissue embedded in a nidus of white fibre. As this figure represents a longitudinal section, the transverse fibres of the yellow element

Fig. 857.

Longitudinal vertical Section of Wall of Subclavian Vein of Ox, treated with Acetic Acid.

a, internal coat; *b*, middle coat; *c*, part of external coat. (Magnified 200 diameters.)

are seen cut across, and appear as small discs : on the other hand, the longitudinal fibres with which they are mingled, are seen in profile, as interlacing and parallel rods : the former gradually diminish, and the latter, in the same proportion, increase, as viewed further and further from the inner surface; and that point where the discs entirely disappear and the longitudinal fibres alone remain may be considered as the external limit of the middle coat. This limit is very clearly seen in a specimen treated with acetic acid (*fig.* 857. *b*); when, as in *fig.* 858. *b*, the section has been transverse, the discs and rods of yellow elastic tissue occupy a position and proportion the reverse of what has been described. The discs are the most abundant on the outer, and the rods on the inner part of this coat, the former being seen in section, and the latter in profile.

This middle coat is very compact, especially near the inner surface, and it gradually becomes less so in proceeding outwards.

It is difficult to tell what is the course and direction of the nidus of white fibrous tissue in which the yellow element is embedded, as in the middle coat it forms a dense granular compact mass*, when seen *in situ*, and its true nature is only displayed by the action of acetic acid. When, however, portions of the tissue are picked abroad with needles, though its direction is lost, its characters are obvious.

As it regards the *muscularity* of this coat, there can exist no doubt. The recent observations of Kölliker on the low form of muscle, which he designates "muscular," or "contractile fibre-cells," have placed this previously obscure subject in an intelligible and satisfactory light, and have done much to explode the idea of non-muscular contraction, by exhibiting the wide diffusion of this hitherto unrecognised tissue.

Kölliker describes two forms of fibre-cells as existing in blood-vessels, — one, consisting of short, round, spindle-shaped, or rectangular plates, like epithelium ; the other, of long plates of irregular, rectangular, spindle, or club, shape. The substance of these cells is soft, light yellow, and homogeneous, and each contains a peculiar, characteristic nucleus, whose shape is constant, being that of a club or staff. These fibre-cells are placed transversely as it regards the vessel, and constitute a thin coat, immediately external to the lining membrane, intermixed with cellular tissue. These muscular elements are clearly seen (as exhibited by their nuclei) by the action of acetic acid on small vessels. (*Fig.* 860.)

He further states that the great development of the uterine veins during pregnancy is principally from an increased size of the fibre-cells existing in the middle coat, but partly also from the inner and outer coat acquiring a considerable quantity of smooth muscular fibre. According to the same authority this muscular element is not found in the veins of the uterine portion of the placenta, the cerebral

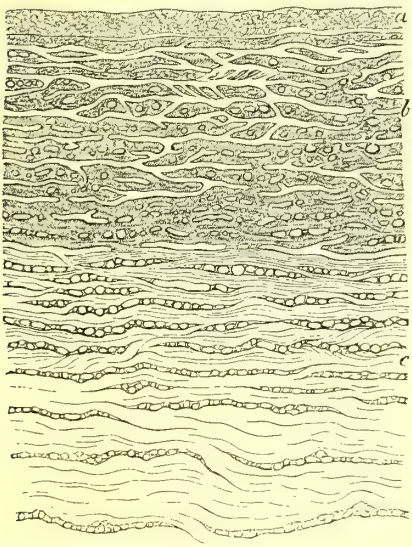
* I would here observe, that when white fibrous tissue is dried and re-moistened, as in these sections, it does not regain all its physical characters: it has lost to a great degree its wavy lines, and hence it is not so easily recognized.

veins, the cerebral sinuses, Breschet's veins of the bones, and the venous cells of the corpora cavernosa.

External coat of longitudinal fibres.—The external coat consists of a mass of areolar tissue, adhering together with more or less compactness, and running in a longitudinal direction.

This tunic occupies full two-thirds of the entire thickness of the whole wall of a vein. Its internal boundary is irregular at the union with the equally irregular outer limit of the middle coat, and its external boundary is the

Fig. 858.



Transverse vertical Section of Subclavian Vein of Ox.

a, internal coat; *b*, middle coat; *c*, part of external coat. (Magnified 200 diameters.)

loose cellular tissue into which it degenerates, and which constitutes the "sheath" of the vessel. This coat, like the preceding, gradually diminishes in density and compactness as it is examined further and further from its inner limit, though its density is everywhere inferior to that of the middle; indeed, it may be said that the tissue of which the vessel is composed becomes looser and looser in proceeding outwards from the inner boundary of the middle coat, — this quality passing gradually from one coat to the other.

The textural arrangement of this tunic must be examined, like the preceding, from longitudinal and transverse sections. In the former it is seen that bundles of rods of yellow elastic tissue are disposed in alternate laminæ with white fibre, or rather, that the former are embedded in a mass of the latter, and that they are a continuation of the longitudinal fibres of the middle coat, which gradually become arranged more and more in strata, and at increasing distances. (*Fig.* 856. *c.*)

The characters of the white fibrous tissue between the bundles of yellow, become more conspicuous as the laminæ are wider apart.

The stratified arrangement of the fibres, and their correspondence with the longitudinal rods of the middle coat are very well seen in the specimen treated with acetic (*fig.* 857.).

When this tunic is viewed in transverse section, the relative thickness and proportion of the lamellæ are better seen than in a longitudinal cut: the yellow element is seen to occupy but a small relative thickness in comparison with the white.

When viewed with a high magnifying power the divided extremities of the rods of yellow fibrous tissue form undulating, and somewhat imbricated lines of discs, while the white fibrous tissue, cut across, shows slight, indistinct, wavy indications. (*Fig.* 858. *c.*)

Seen with a low power, the ends of the yellow fibrous tissue appear as series of dark undulating dots on a field of white.

Minute veins. — When very small veins, a few removes from capillaries, are examined microscopically, they merely present faint striations in the longitudinal direction. When, however, these vessels are treated with acetic acid, nuclei and fibres are distinctly displayed, whose long axis may be assumed to indicate the direction of the tunic (or set of fibres) which they represent, in which they are embedded, and of which they form a part.

Henlé was, I believe, the first to point out this mode of textural dissection of vessels, and nothing can be more satisfactory than the analysis that it makes. By this means small vessels alone can be examined, but the scrutiny may be carried up to those the third of a line in diameter, which are sufficiently transparent, when entire, to exhibit the nuclei. Small vessels may be conveniently obtained from the pia mater and mesentery; they are there free from other structures, and their form is not interfered with.

I have found, however, that it is in the pia-mater somewhat difficult to trace the small *veins;* the arteries about them are more definite and conspicuous, and less injured by manipulation, and generally catch the attention of the observer. It has been more convenient to obtain isolated cerebral veins from the surface of the ventricles of the brain; the small veins on the corpus striatum may be raised and torn away with the points of fine forceps, and sufficient capillaries will generally be found attached to their extremities to exhibit the structure of these vessels of all sizes. The accompanying figures were made from specimens thus obtained, about whose venous character there could be no mistake.

Small veins vary in structure in different regions, and according to their size; some ap-approach the structure of arteries *, whilst

* It may be convenient here to give a brief outline of the anatomy of *capillary,* and *minute, arteries.* Their structure is more definite than that of veins; their walls are thicker and their cavity less in proportion. The larger ones exhibit both a longitudinal and a transverse striation. When treated with acetic acid the nuclear corpuscles are *numerous, sharply defined,* and *obvious in their direction.*

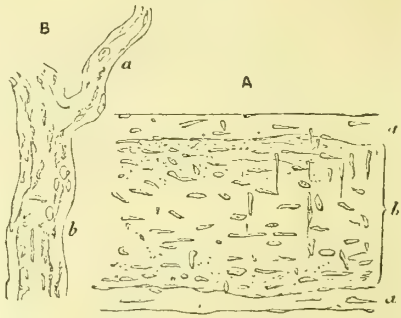
Capillaries, up to about 1-1600th of an inch in others are far removed from them in composition.

Venous capillaries do not, that I am aware of, differ from arterial. They consist of tubes of homogeneous membrane, studded here and there with nuclei of a more or less oval form, and placed generally with their long axis corresponding with that of the vessel. In passing to larger veins the change in structure of the vessel (its increase and character) depends upon the region from which it is obtained, and whether or not it is endowed with muscle-cells.

In the cerebral veins, which have no muscle, in passing from small capillaries to larger vessels, all that is observed is the superaddition of a tunic of areolar tissue, surrounding the lining membrane; and when this tissue is treated with acetic acid, all that is observable is a series of nuclei, oval, irregular, and longitudinal, embedded in the substance of the parietes, which have a perfect resemblance to the external, or cellular coat of small arteries. (*Fig.* 859. A.) In none of the microscopical cerebral veins have I been able to discover any nuclear or yellow fibres. In veins of the $\frac{1}{50}$ to $\frac{1}{100}$ of an inch the vascular wall has been composed of a tissue rendered transparent by acetic acid, and displaying oval and irregular nuclei having a longitudinal course, without any admixture of elastic *fibre*. The most internal of the nuclei appeared elongated, but there was no appearance of fibres upon the internal membrane, so as to produce a striated membrane.

In those veins which are endowed with muscular tissue, small club-shaped nuclei are observed placed externally to the lining mem-

Fig. 859.



A, *Minute Cerebral Vein* (*about* 1-200*th of an inch diameter*), *from Sheep, treated with Acetic Acid.* *a*, wall; *b*, cavity.

B, *Venous Capillaries* (a, *about* 1-1600*th of an inch* b, *about* 1-600*th of an inch*) *treated with Acetic Acid.*

In both these figures persistent nuclei of areolar tissue and epithelial nuclei are alone visible. (Magnified 200 diameters.)

brane, and transversely as it regards the vessel; these show themselves very distinctly on the addition of acetic acid, and are characteristic of the "muscular fibre-cells" of Kölliker. Such may be seen in the small veins of the mesentery, which are more easily examined than any other veins of this class. In these vessels, two or three removes from capillaries, the muscular nuclei make their appearance, at first, few in number and irregular; and in still larger, but microscopical veins, these nuclei are seen to be mixed up with, or covered in by, more or less areolar tissue, which at first is destitute of *nuclear fibre*, but contains conspicuous *nuclei*, oval and irregular in shape and longitudinal in direction. In the accompanying drawing (*fig.* 860. B) is a small vein from the mesentery of a rabbit, measuring about $\frac{1}{250}$ of an inch in diameter, and treated with acetic acid. On the lining membrane are seen a few elongated nuclei and longitudinal striations, constituting a sort of incipient *striated membrane*. External to this is a thin layer of muscular tissue, and without that, again, is cellular tissue, which constitutes the main bulk of the vascular wall. The muscular coat is less distinct than in arteries of the same size and thinner in proportion to the areolar coat.

Such veins have, however, a strong resemblance to small arteries. Henlé states that the two systems of vessels are not to be distinguished in those measuring up to $\frac{1}{600}$ of an inch; and he appears to consider *thinness of wall* as the main characteristic in larger microscopical veins. He instances one vessel, which he considers as venous, measuring $\frac{1}{56}$ of an inch in entire diameter, having an annu'ar tunic $\frac{1}{660}$, and a cellular $\frac{1}{1985}$ of an inch. It has appeared to me that the differences of these vessels are principally these, — microscopical veins have thinner walls; the mus-

diameter, consist of tubes of homogeneous membrane, studded here and there with nuclei of an oval form, whose long axis is that of the vessel, except in the larger ones, where a few are placed transversely. These corpuscles are elongated, and more numerous, in the larger capillaries.

In arteries about 1-600th of an inch, the walls consist of a homogeneous tube, with the nuclei on the outer surface still more elongated; and external to this, a set of nuclei, club-shaped and sharply defined, placed at right angles to the former, and representing the circular (muscular) tunic in which they are embedded.

In larger arteries a cellular tissue, still more external, is seen, whose corpuscles — oval and irregular — are longitudinal. In such arteries (say, about 1-300th of an inch in diameter), the tunics are, 1st. a homogeneous tube covered with elongated longitudinal nuclei; 2nd. a circular tunic, represented by the club-shaped transverse nuclei; and 3rd. a longitudinal tunic of cellular tissue, in which are imbedded oval and irregular nuclei. In passing to larger vessels, the nuclei of the internal coat elongate and disappear; and the internal membrane then consists of perfect striated membrane, the homogeneous tube being covered with very fine longitudinal fibres of elastic tissue. Such may be seen in arteries of 1-100th to 1-60th of an inch in diameter, and in some much smaller. Fibres make their appearance shortly afterwards in the circular tunic, intermixed with the club-shaped nuclei.

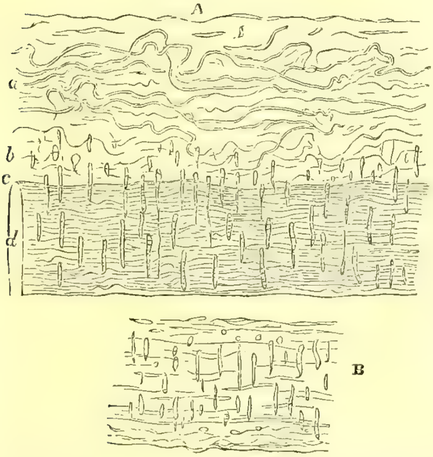
The proportion existing between the diameter of an artery and the thickness of its walls is subject to considerable variety; and the same may be said of the *relative* thickness of the several tunics which compose the wall.

Henlé has given good figures of the structure of arteries.

cular tunic is less distinct, thinner than the areolar, with which it is more or less mixed up, and the latter is more abundant and more developed than in small arteries.

In passing to vessels of larger size, the fibrous tissue is seen to have a more conspicuous development. The longitudinal stri-

Fig. 860.



A, *Small Portion of the Margin of a compressed specimen of the Renal Vein of a Rabbit, treated with Acetic Acid.*

a, external longitudinal coat, exhibiting yellow fibres and persistent nuclei of areolar tissue; *b*, middle circular tunic, showing nuclei of muscle cells; *c*, internal longitudinal coat (striated membrane), the limit of the vessel's cavity; *d*, corresponds to a small portion of the cavity of the vein.

B, *Minute Vein from Mesentery of Rabbit, exhibiting the three Tunics less distinctly.* (Magnified 200 diameters.)

ations and fibres on the lining membrane form a perfect *striated membrane*, and, in still larger vessels, increase so as to constitute a compact coat of fibres, of more or less density — the *internal tunic of longitudinal fibres.* In the middle coat, the muscular element becomes involved and mixed up with areolar tissue, some fibres of which run parallel, and some at right angles to the muscular nuclei. The external tunic of areolar tissue becomes increasingly developed, and yellow fibrous tissue conspicuous and abundant.*

In *fig.* 860. A, is represented part of the renal vein of a rabbit. The vessel is not cut open or seen in section, but is simply laid upon glass, treated with acetic acid, and a small portion of the margin submitted to microscopical scrutiny. The internal membrane is densely striated, and the other coats developed in proportion.

* In the comparative examination of small and large blood vessels, there is much to confirm Henlé's doctrine of *nuclear* and *cell fibre.* In the capillaries, which are mere tubular cells, there is no fibre, and the nucleus is persistent; in larger vessels, where fibrous tissue is developed, the nucleus disappears and yellow fibre is found: but in those veins which retain abundant persistent nuclei, as the cerebral veins, even in those of larger size, no nuclear fibre is detected.

There are certain regions in which the veins undergo striking modifications in structure, which require description; and the remarkable organs — valves — placed in their interior are yet to be considered.

These points will be examined as follows: —

I. Veins, at their junction with the heart.

II. Cavæ, passing through the diaphragm and pericardium.

III. Cerebral sinuses.

IV. Umbilical vein.

V. Venous valves.

I. *At the junction of the veins with the heart* there is a great alteration in their composition, and this as it respects *both cavæ*, and the *pulmonary veins:* they assume a muscular character, and become thicker and red, which arises from a prolongation of the muscle of the auricle into the fibrous structure of the vein.

This anatomical fact, as far as the cavæ are concerned, was described as early as 1664, by Borelli; subsequently (1700), by Bidloo, who gave figures of it; and afterwards (1779), by Gorter, who imagined that the muscle was continued into the smaller vessels, and that it there assumed a paler colour.

This muscular layer (though its existence is denied by Cruveilhier) may be followed upon the superior vena cava as far as the clavicle, upon the inferior as far as the diaphragm, and upon the pulmonary veins as far as the division of the trunks into branches. (*Henlé.*) It exists on the superior cava in greater amount than on the inferior, and it is there best submitted to examination. When viewed with the naked eye, the vena cava superior, at its junction with the heart, is seen to be red and muscular, and thicker than elsewhere. In following this away from the heart, the muscular character gradually diminishes, and the ordinary fibrous tissue assumes the preponderance till the former is altogether lost. At ten lines from the junction of the vessel with the heart the mass was removed from which the accompanying drawing was taken.

The cavæ of some birds are sufficiently thin and transparent to be viewed with transmitted light when entire, and when slit up and held to the light a beautiful arrangement of these fibres is seen: they do not form one flat, even, circular, covering, but are arranged in numerous, successive, interrupted, rings, very fine and red, gradually diminishing as they are seen further from the heart. I have observed this in the red-throated diver (*Colymbus septentrionalis*), moor-hen (*Gallinula chloropus*), and various other birds. According to *Cuvier*, in the ostrich, muscular fibres extend the whole length of the posterior cava, and disappear suddenly opposite the kidneys.

When a little mass of this structure is examined with the microscope, it is found to consist of muscle of the same character as that of the heart, — the fibres being small, striped (though, perhaps, rather less distinctly so than that of the auricle or ventricle), and, as far as I have seen, destitute of sarcolemma. There is a good deal of wavy fibrous tissue, intermixed with the muscle; in this respect, contrasting remarkably with that of the heart: this exists in less amount in the immediate vicinity of that organ.

There is yet another peculiarity in the structure of the great veins near the heart,—they have a partial investment of the serous layer of the pericardium; this, however, exists only on the anterior surface; and in the inferior cava the amount of serous covering is very small.

Fig. 861.

A Mass of Muscular Fibres from the Middle Coat of the Superior Vena Cava of the Human Subject, eight or ten lines above its junction with the Auricle. (Magnified 200 diameters.)

II. *When the cavæ pass through the pericardium and diaphragm* they contract an intimate connection with those structures whose fibrous tissue is more or less reflected upon them and adds to their coats. Upon the superior cava are to be seen (external to the pericardium) white, glistening fibres, having a longitudinal course, and traceable from the pericardium directly upon the vein. The pulmonary veins have a similar covering.

In the human subject, the inferior cava passes through the pericardium and diaphragm at once, and there forms so intimate an adhesion to the margin of the aperture that I have removed *striped* muscle (of the diaphragm) from the fibrous tissue of the vessel, it having taken its origin from the outer tunic of the vein.

In many of the lower animals (as in the *sheep*, *cat*, and *rabbit*,) there is a considerable interval between the diaphragm and pericardium, in which the vena cava inferior is invested with a covering of fibrous tissue contributed from both these sources. It is white, glistening, and strictly longitudinal, and is furnished in largest amount by the pericardium.

III. *Cerebral sinuses.*—The cerebral sinuses hold the place of large veins to the brain, but are materially different from large veins in structure. They consist of excavations or tubes in the substance of the dura mater,—the dura mater is, as it were, split into two layers, and the interval is the cavity of the sinus. Their form, which is very irregular—triangular, quadrilateral, &c.—differs in different situations.

The internal or lining membrane of the sinuses is stated by all anatomists to be identical with that of the veins; but its exact amount and nature I have not myself ascertained. The continuity of the lining membrane with that of the veins is seen where the sinuses join the veins; thus, at the cavernous sinus, where the ophthalmic vein and circular sinus join it, the lining membrane adheres to the inner wall of the sinus, but is separated from the outer by the carotid artery and certain nerves. The other element of the walls of these peculiar veins is the white fibrous tissue of the dura mater, arranged without any regularity. The inner surface of these vessels is smooth, but rendered extremely irregular by the occurrence of numerous fibrous processes on bands projecting into their cavity. In the *superior longitudinal sinus*, the *cavernous*, and *middle basilar*, this is most conspicuous. In the first mentioned of these, the fibrous bands have been called "*cordæ Willisianæ*" (after Willis, their first describer). They are slips of white fibrous tissue passing from the sides of the sinus, especially near the angles, attached at both extremities, and either free or attached along one side: these give the appearance as if the inner surface were divided into cells; into some of these the probe enters and passes on into the veins on the surface of the brain; others are blind, or lead to lesser sinuses, which not unfrequently run parallel, for some length, to the great sinus; or the probe passes from one of these cells to another. In the cavernous sinus these fibrous bands are so numerous that they look like a mass of areolar tissue, whose areolæ are distended with blood. The cordæ Willisianæ are traversed by minute arteries. (*Sir C. Bell.*)

IV. The *umbilical vein* has a structure quite peculiar to itself. The vessel may be best examined by splitting it up with a director and pinning it down on cork, with its inner surface upwards. It is then seen to be smooth, valveless, and whiter than other veins.

From the inner surface I have obtained epithelium: the cells were flat, irregular in outline, granular and fatty.

On making an incision, the membrane of which it is composed retracts, so as to leave a gap, and displays the dense fibrous mass which forms the basis of the cord. It tears off in irregular shreds, not showing a tendency to tear in any particular direction. With care, considerable portions of the membrane may be stripped off. This structure is soft, elastic, and semi-pellucid. It appears structureless to the naked eye, and looks almost like a thin film of fecula jelly (arrow-root made with water), or rather, perhaps, like the flaccid dull cornea of an animal dead some days. When separated, it coils up, and, where the surfaces have become adherent, it is difficult to unfold it again: it now looks and feels like thick mucus—it is semitransparent and adhesive. When seen under the microscope, it is found to be indistinctly fibrous; some masses appear as a dense web of flat fibres, the fibres being strictly on the same plane, with their sides adherent at some points, and leaving intervals at others; in some places the interspaces are only small specks on the surface of what appears to be in other respects, an almost homogeneous sheet; there are also some indistinct longitudinal striations, connecting these minute interspaces and obscurely indicating the outline of fibres. The element of which this coat is composed is singularly pellucid under the microscope, scarcely refracting excepting at its edges.

The fibrous mass of which the vein is composed, in many places exhibits the appearance as if the fibres were formed of spindle-shaped cells strung together, with their ends overlapping; and these cells may be occasionally isolated,—they are spindle-shaped and have an oval nucleus. They resemble those obtained from the middle coat of the aorta of a fœtal pig, by Lehmann. (See his figure.)

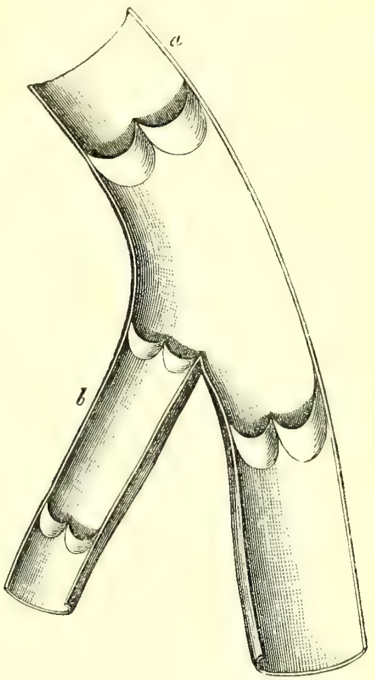
Whether this condition is the result of imperfect maturation of the tissue of which the vein is composed, or otherwise, I am unable to say.

V. *Valves.* — The valves are membranous folds on the inner surface of the veins, having a definite form and regular arrangement with regard to their object—*the progress of the venous blood to the heart, and obstruction to its regurgitation.* They are of peculiar interest to the physiologist, as presenting a clear and elegant specimen of animal mechanics; and to the literary anatomist they are not less interesting, as having been one of the main objects which suggested to Harvey his brilliant deduction of the circulation of the blood.

Cruveilhier states that the valves of veins were first discovered by Etienne. Harvey leaves the priority of discovery in doubt; for he writes, "The celebrated Hieronymus Fabricius of Aquapendente, a most skilful anatomist and venerable old man; or, as the learned Riolan will have it, Jacobus Sylvius, first gave representations of valves in the veins."* Fabricius himself lays claim to the discovery, "non solum nulla prorsus mentio de ipsis facta sit, sed neque aliquis prius hæc viderit, quam anno Domini septuagesimo quarto, supra millesimum et quingentesimum, quo à me summa cum lætitia inter dissecandum observata fuêre."† Marx, who appears to be profoundly versed in the literature of this subject, says the discovery is due to Erasistratus; for he observes, "Erasistratus (304 B.C.), item clarus anatomus jam subtilius in structuram et usum venarum inquisivit, valvulas jam observavit."*

Harvey's description of the valves is so apposite and clear, as well as so interesting in a literary point of view, that I shall quote it. The valves, he observes, "consist of raised or loose portions of the inner membrane of these vessels, of extreme delicacy, and a sigmoid or semilunar shape. They are situated at different distances from one another, and diversely in different individuals; they are connate at the sides of the veins; they are directed upwards or towards the trunks of the veins; the two—for there are, for the most part, two together—regard each other, mutually touch, and are so ready to come into contact by their edges, that if any thing attempt to pass from the trunks into the branches of the veins, or from the greater veins into less, they completely prevent it; they are further so arranged, that the horns of those that succeed are opposite the middle of the convexity of those that precede, and so on, alternately." He further writes, "In many places two valves are so placed and fitted, that, when raised, they come exactly together

Fig. 862.



Venous Valves, after Fabricius.†

a, femoral vein; *b*, saphena interna.

* Harvey on the Motion of the Heart and Blood, Sydenham Society's Translation. chap. xiii.

† Fabricius, ab Aquapendente. Opera omnia Anatomica, &c. Lips. 1687, p. 150. Fabricius calls the valves by the felicitous term, "osteola," *little doors.*

* Marx. Diatribe Anatomico-physiologica de Structura atque Vita Venarum. Carls. 1819, p. 6.

† Fabricius, Opera omnia, tab. iv. p. 157.

in the middle of the vein, and are there united by the contact of their margins; and so accurate is the adaptation, that neither by the eye, nor by any other means, can the slightest chink along the line of contact be perceived. But if the probe be now introduced from the extreme towards the more central parts, the valves, like the flood-gates of a river, give way, and are most readily pushed aside."*

Valves exist in two different situations; namely, at the orifices of lesser veins where they join the trunks which they supply, and in the canals of veins, arranged at various points.

Fig. 863.

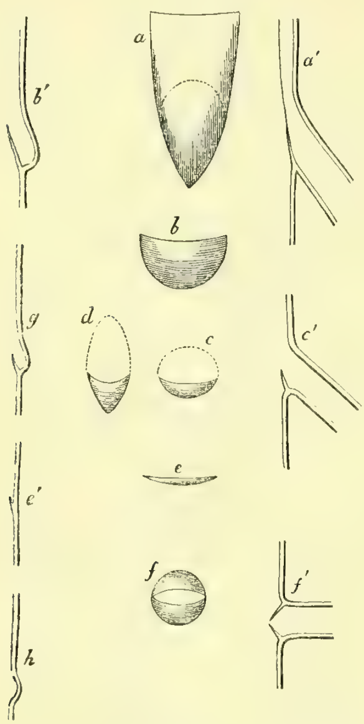


Diagram exhibiting different forms of Valves.

a, valve placed at the orifice of the renal vein in the sheep, seen in face; *a′*, the same in ideal section; *b*, the ordinary semilunar valve from the tube of a vein; *b′*, the same in section; *c*, imperfect valve at orifice of intercostal vein; *c′*, section of imperfect valve at orifice of hepatic vein; *d*, the same in face (the dotted lines in *a*, *c* and *d* correspond to the orifices of the respective veins); *e*, very imperfect valve; *e′*, the same in section; *f*, plan of double valve at orifice of vein; *f′*, the same in section; *g*, ideal section of small valve and sinus; *h*, section of sinus without a valve.

At the orifices of veins the valves are either single or double: when single, the free margin always looks towards the heart. In the canals of veins the valves are usually double in the larger, and single in the smaller. It is rare, in the human subject, to find them in threes on the same plane, though it has been found both by Morgagni and Haller; but in the great vessels of the larger mammalia it is common. There are none in the capillaries; but, according to Henlé, in veins of not more than half a line in diameter, they make their appearance.

* Loc. cit.

For the purposes of anatomical description a valve may be said to have a *body*, *margins*, and *cornua*. The body of the valve has a *cardiac*, *concave*, or *proximal face* and a *convex* or *distal face*. The margins are,—the *free*, or that which is unattached, and the *attached margin*. The *cornua* are the angles formed by the meeting of the two margins, and constitute the extreme lateral boundaries of the valve.

Valves differ from each other very considerably in form, varying from a mere linear elevation on the inner surface, in which the probe scarcely hitches as it is pushed along, to others which almost form a long isosceles triangle. The outline of the margins determines the form of a valve. Cruveilhier says that the free margin is always straight; but this is not the fact, though it is always more so than the attached.

In the first attempt at a valvular formation there is merely a slight elevation of the inner surface, and the free and attached margins are nearly parallel: these scarcely constitute valves. (*Fig.* 863. *e*, *e′*.)

Valves, still imperfect but of larger dimensions, are found at the orifices of veins, as well as in their canals. When existing in the former situation (and this is applicable to all valves thus placed), their attached margin corresponds with the side of the orifice which is furthest from the heart, and the outline of this margin is determined by the form of the vessel's mouth. If the lesser vessel joins the greater at right angles, the opening will be circular, and the attached margin of the valve a semicircle. If, however, the junction be oblique, and an acute angle be formed by the two vessels, then the margin attached will be drawn out of the semicircle, so as to form a sort of apex in the centre. The former of these conditions is shown at *fig.* 863. *c*, taken from a small valve at the orifice of an intercostal vein, joining the azygos; and the latter is represented at *d*, which is a drawing made from a valve at the orifice of an hepatic vein, where it joins the vena cava: *c′* is an ideal section of the same. The dotted line in *a*, *c* and *d* represents, in conjunction with the line of the attached margin of the valve, the orifice of the tributary vein.

The next form, in order, and the one which is the most common, is the *semi-lunar** valve, as it is ordinarily found in the tube of valved veins,—the attached margin being nearly semicircular, and the free nearly straight (*fig.* 863. *b*). It was probably of these valves that Haller spoke when he said that *the attached margin of valves constitutes a parabolic curve:* it may be applicable to some of the semi-lunar,

* Fabricius, not inaptly, described them as resembling a finger nail, "forma ostiolorum ea est, ut indicis unguem imitentur."—Loc. cit. p. 151.

but it cannot be to valves in general: a parabola is a constant form, but the outline of the valves is various. It appears to me that the outline of a valve rather conforms to the ellipse, the curve being sometimes very much elongated, sometimes nearly approaching a circle. An ellipse is obtained from a cylinder, by an oblique section of it; an oblique section of a cylinder will only give an ellipse. For the line of attachment, therefore, of a valve with the cylindrical surface of a vein to generate an elliptical curve, that line of attachment must coincide with an oblique section of the cylinder: and we see that this is frequently the case, that is, when the valve is viewed in profile, its attached margin forms a right line at an angle, more or less acute, with the wall of the vein, the acuteness of the angle determining the elongation of the ellipse. This is represented in *fig.* 864. B, where *a* shows the line of attachment seen in profile, and *a′* the curve generated by that line when seen in face. But sometimes the attached margin does not form, when viewed laterally, a straight line, but is more or less curved, as seen at *fig.* B, *b b′*, and then we necessarily get

Fig. 864.

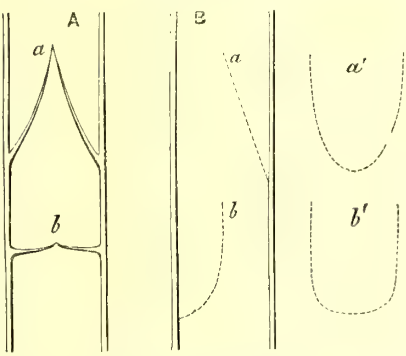


Diagram exhibiting the Attachment and consequent Forms of Valves.

A, section of valves in action. *a*, elongated elliptical valve; *b*, broad semilunar valve.

B, exhibits the lines of attachment of, *a*, elliptical valve in profile, and *a′*, the resulting form; *b*, the attachment of parabolic valve in profile, and *b′*, the resulting form.

an aberration from the ellipse, and an approximation, more or less near, to the parabola. Now, in such valves as are placed in pairs in the canals of veins, with their convex faces opposing and their cornua in contact, their relative length and breadth depend upon the obliquity of their attachment, — the requirements being constant, namely, that the opposed valves should meet by their free margins in a line across the centre of the vessel, — for if the attachment be oblique and extend more in the axis of the vessel, it will require a much deeper valve to reach its fellow in the centre, than if the attachment were more across the tube, where a short, broad valve would accomplish the object. These two conditions are represented in the figure (*fig.* 864. A.), which is an ideal section of a vein, in which both forms of valves are seen in a state of action.

Valves in the canals of veins, though in contact by their cornua, are sufficiently loose and large to fall back fully upon the sides of the vessels to allow the progressing current to pass on uninterruptedly.

A valve the furthest removed in form from those first mentioned, is represented in *fig.* 863. *a*, which is the drawing of a valve situated at the orifice of the emulgent vein, where it joins the inferior cava in the sheep. Its depth is very considerable in proportion to its width, and the centre of its attached margin is nearly an acute angle, produced by the angle at which the renal vein joins the cava.*

Structure of valves. — A venous valve consists of a thin fibrous lamina, protruded into the tube of the vessel.

If the attached margin be carefully cut from the wall of a vein, and the organ be extended upon a slip of glass, it is seen to be thin at the free margin and thick at the attached; if it be viewed by transmitted light, with the naked eye, it will be seen that the body of the valve is divided, rather indistinctly, into two portions, of which the free half is thinner and bluish-white, while the other is much thicker, and of a yellowish colour; the line of demarcation, between these, extending across the body of the valve about parallel with the free margin; this however, does not exist, in some valves.

The examination of a valve with the microscope requires that it should be completely unfolded at its free margin, in the neighbourhood of which, in the larger valves, its structure can alone be successfully observed, on account of the thickness and opacity of the other parts of the valve. When removed from a vein it should be placed upon a slip of glass, moistened, and, the attached margin being seized with forceps, it should be drawn over the surface of the glass so as to unravel any folds of the free margin, which are apt to occur.

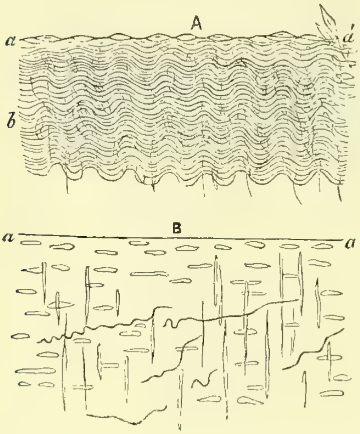
The *epithelium* cannot always be found on the face of the valve, and to see it the body must be very thin, and the focus of the instrument be thrown superficial to the fibrous lamina, when their nuclei will sometimes be viewed pretty distinctly. They are scattered evenly over the surface, but the cell-wall is extremely ill-defined, or not to be made out. At the margin of the valve they are frequently to be seen in one or two conditions, — free, detached nuclei, accidentally adherent along the margin; or cells, seen edgewise, with conspicuous nuclei, as already described.

The *fibrous lamina* is the most conspicuous element of the valve, and constitutes its bulk. It consists almost entirely of white fibrous tissue, extending from side to side of the valve, running parallel with the free margin, and continuous, apparently, with the circular coat of the vein on each side of the attached

* The extreme depth of the valve here represented is not constant; it sometimes barely reaches across the orifice.

margin of the valve. The fibres are singularly regular, and present the most beautiful and equal undulations, as if each fibre were of exactly the same size and extent; and the undulations of all succeeding fibres are precisely similar, as far as the tenuity of the structure towards its attached margin is sufficient to allow of its examination. These fibres may be looked upon as a portion of the circular coat protruded into the cavity of the vein.

Fig 865.



Small Portions of the Valves from a Sheep.

A, The valve showing a line of epithelial nuclei at the extreme margin *a a'*; *a'*, detached nuclei; *b*, small portion of face of valve, exhibiting wavy fibres, epithelium and muscle.

B, the same treated with acetic acid. *a a*, margin. On the face of this valve are seen two sets of nuclei; and fine threads of elastic fibre. (*Magnified* 200 *diameters.*)

Running at right angles to these, and placed upon a different plane, are to be seen fibres or elongated corpuscles of a spindle shape, and of very variable distinctness. These corpuscles are apparently muscular fibre-cells: they are very conspicuous in some specimens, and very indistinct in others; whilst in others they cannot be discovered at all.

On treating a valve with acetic acid, two sets of nuclear corpuscles are to be discovered, running at right angles to each other. Those which are parallel with the wavy fibres of the fibrous lamina are mainly oval, interspersed with a few more elongated; and those, cutting the former at right angles, and being parallel with the muscular fibre-cells, are club-shaped and spindle-shaped, having a strong resemblance to the nuclei of muscular fibre-cells. The former, as it appears to me, are mainly persistent nuclei of areolar tissue, and belong to the wavy fibres, whilst the latter are evidently muscular nuclei. Small threads of yellow fibre are occasionally seen. They are very fine, detached and scattered; and frequently exhibit a spiral form. In examining these structures it is necessary that, when removed from the body, they should not be allowed to dry before the observations are completed; for the characters both of the fibrous lamina and nuclei are impaired permanently if they have once been dry.

Sinuses. — There is yet another item in the valvular apparatus of venous canals, — the occurrence of *sinuses* in the walls of the veins. These consist of small pouches or dilatations in the walls of the veins immediately in front of the valves. By these, the cylindrical form of the vessel is lost at that spot, two bulgings being apparent on it. These bulgings produce a certain amount of attenuation at these points, the thinness being in direct proportion to the increased area produced. The sinuses vary in dimensions, and do not bear any exact proportion to the size of the valve. Lateral dilatations may be seen in the walls of veins where no valves are present. (See *fig.* 863., *b'*, *g*, *e'*, *h.*) When the valves are in action, these distended sinuses present knots along the course of the vessel; an appearance first described and figured by Fabricius: he observes of them, " non dissimilem formam exterius præ se ferentes, *ac nodi in plantarum ramulis, et caule* apparent." *

The supply of valves in the venous system is only partial, and is irregular. Valves are only found (in the human subject) in those veins which are subjected to muscular pressure, and are, therefore, most abundant in the veins of the limbs: and it has been well laid down by Cruveilhier, " that their presence and their number, their proximity and their distance from each other are directly influenced by the degree of opposition to the onward progress of the blood in any set of veins." †

Of the veins of the head and neck, the external jugular is the only one with valves: it possesses two, which however are not sufficiently compact to oppose injection. There are none in the cerebral sinuses or veins, and none in the internal jugular. The veins of the upper extremity are abundantly supplied with valves, which appear to be somewhat more numerous near the upper part of the arm. There are valves in the axillary vein, but none in the subclavian, vena innominata, or superior cava. They are abundant in the lower extremity, but most numerous at its lower part; in this respect differing from the superior extremity. The branches of the internal iliac vein are supplied with valves, while the external and internal iliacs themselves, the common iliac, and the inferior cava, have none. The spermatic veins (male) have valves, while the ovarian (female) are destitute of them. In the azygos veins, Cruveilhier denies the existence of valves, but they are occasionally found in an imperfect state of development.

The spinal veins are destitute of valves, as are, also, those of the portal system, the hepatic veins, those of the heart, kidney, uterus

* Loc. cit. For figures of these " *nodi*," see Fabricius, Opera omnia, tab. II. p. 157.; also Harvey, De Motu Cordis et Sanguinis in Animalibus, Anatomica Exercitatio. Lugd. Bat. 1639, p. 187.

† Cruveilhier. Anatomie Descriptive.

and lungs. Comparative anatomy and accidental aberrations from nature furnish some exceptions to the foregoing statements. Meyer has found incomplete valves in the pulmonary veins. Theile has found valves in the ovarian veins. E. H. Weber has observed them in the portal veins of the horse; and Cuvier, in the same animal, has found them in the splenic and mesenteric veins. Haller has discovered valves in the pulmonary veins of the dog and sheep.

Valves exist but sparingly in *Birds* and *Cetaceans*; and in *Reptiles* and *Fish* are almost wanting.

The *office of valves* is to prevent the blood from effecting a retrograde course; "lest, instead of advancing from the extreme to the central parts of the body, the blood should rather proceed along the veins from the centre to the extremities; but the delicate valves, while they readily open in the right direction, entirely prevent all such contrary motion; being so situated and arranged, that if any thing escapes, or is less perfectly obstructed by the cornua of the one above, the fluid, passing, as it were, by the chinks between the cornua, is immediately received on the concavity of the one beneath, which is placed transversely with reference to the former, and so is effectually hindered from getting any farther."* This refers especially to the valves in the venous canals. There is a peculiarity about those placed at the orifices of veins. I have already remarked that all *single* valves placed at the mouths of veins are *attached* to the distal margin of the orifice: the *free* margin looks towards the heart, the concave face obliquely towards the cavity of the tributary, and the convex in the opposite direction. Now it is obvious from this arrangement, that when the blood falls back upon the concave surface of such a valve, it throws it more or less across the area of the larger trunk, and away from the orifice of the smaller vessel, over which it forms no protection. The office of the single valve, thus placed, appears to be not to guard the *small veins*, or to prevent the retrocessant blood from passing into it, but to oppose the blood which it supplies from passing into that portion of the recipient vein which is behind the orifice of the tributary: the valve, as it were, directs the blood into the onward track of the great vein, and prevents it from taking an opposite course.

The case, however, is different where the valvular apparatus is *double*, for there a valve is placed at the proximal, as well as at the distal margin of the orifice: now the former of these valves prevents the blood from passing behind the other into the smaller vein — the two valves mutually assist each other, and prevent the blood from passing behind either; and the result is a complete obstruction to all retrograde circulation into the smaller vessel. The important object of exclusion of venous blood from the thoracic duct is thus effected.

* Harvey, loc. cit.

Valves are essentially *passive* organs in the circulation; and they only avail when motion is given to the circulating fluid by other means, — they determine *what shall*, and *what shall not*, be the direction of the moving fluid. The contraction of the muscles is one of the great motor agents of the venous circulation. When a muscle contiguous to a vein contracts, the vessel is compressed and the blood forced out of it; and, were it not for the valves placed at the distal side of the compressed point, the blood would be sent as much from, as towards, the heart. Autenrieth has put this in a striking point of view; he says, "Each swelling muscle becomes thereby, for the neighbouring veins, a kind of heart furnished with valves; thus, while it presses the vein, the valves prevent the blood in the lower part of the same from being driven backwards; but, in the upper part, opening valves are placed, from which the blood, driven forth by the contracting muscle, meets with no opposition in its direction towards the heart. It is from this circumstance that each violent movement of the body, which consists in an alternate swelling up and sinking down of the muscles, has so great a tendency to accelerate the circulation; naturally, however, while the muscles are in a state of repose, the valves cannot facilitate the movement of the blood."*

The function of the sinuses is this, — to receive the valves when they are folded back, during the onward current of the blood; and to allow the blood to pass behind them and to throw them across the area of the vessel when that fluid regurgitates.

Vasa vasorum. — The coats of all blood vessels, except those of very small size, are supplied with arteries and veins especially devoted to their nutrition, called "vasa vasorum."

According to Henlé, vessels (veins and arteries in common) receive vasa vasorum, though themselves not larger than $\frac{1}{24}$ of an inch in diameter, and sometimes even smaller. The coats of capillaries and those of the smallest vessels are not thus nourished by a separate vascular supply.

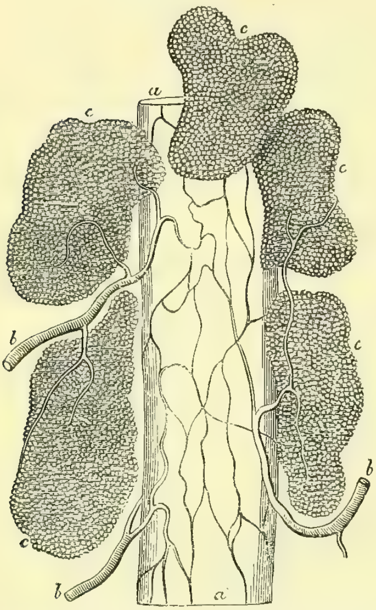
The nutrient arteries of the venous coats are derived from the small arterial trunks in the vicinity of the vessel†; they do not come directly from larger arterial trunks, but from smaller vessels; and the source of the vascular supply is determined by the particular neighbourhood of the vein — the same vessel having vasa vasorum from different sources as it passes along different regions: thus, the *vena azygos* is nourished by the intercostal, pericardial, and œsophageal, arteries, according to its various relations as it proceeds along its course. The arteries supplying the tunics of a vein, appear to go promiscuously to the vessel and the adjacent tissues, sending some of its ramules to the areolar tissue, nerves, fat, &c., in the neighbourhood, and others to the walls of the vessel. In the accompanying figure, repre-

* Autenrieth. Physiologie, §§ 388, 389.

† The artery usually has its vascular supply from the same source as the vein which accompanies it.

senting a vein from the œsophagus of an eel, magnified with low power, the vasa vasorum are seen to supply, indiscriminately, the vessel's coats and some small pellets of adipose tissue which were near it. The arteries, nourishing a vein, ramify and divide principally upon, and among, its cellular coat, and form an elaborate plexus, with meshes having a general longitudinal direction, as seen in the figure; which,

Fig. 866.



Vasa Vasorum on external surface of a small Vein from the œsophagus of eel. (*Anguilla acutirostris.*)

a a, vein; *b b b*, small arteries supplying indiscriminately the venous tunics and small masses of fat around the vein; *c c c c c*, granules of adipose tissue. Natural injection. (*Magnified about* 18 diameters.)

though drawn from a fish, sufficiently indicates the condition as found in man and mammals. The arrangement of these capillaries is, however, subject to variety: in the vena cava of the cod, I have seen them long, straight, even, and perfectly parallel, with scarcely any transverse branching or anastomosis. The little venous trunks of the vasa vasorum usually open directly into the cavity of the vein, among whose tunics they have previously ramified, and their course is quite independent of the corresponding arteries. (*Henlé.*)

The vasa vasorum principally exist in the areolar tunic, but Henlé states that they are to be found abundantly among the annular fibres of the veins.* The internal longitudinal coat is, in all cases, extra-vascular.

Nerves of veins. — As far as our knowledge hitherto goes, veins differ remarkably from arteries in rarely being made the support of nerves, and in seldom receiving any distribution of them to their coats. It is a remarkable circumstance that veins appear, with slight exceptions, to be separated from nerves. The exceptions to this rule are few and inconsiderable.

The *inferior vena cava* receives some small filaments from the diaphragmatic ganglion of the sympathetic, just below the diaphragm. The *vena porta* supports and is entwined by the branches of the hepatic plexus, which it conducts to the liver. Pappenheim describes some nerves as being distributed to the *cerebral veins.* Bidder states that he has traced some filaments of the fourth cerebral nerve to the *lateral sinus:* and Wrisberg describes a nervous plexus as surrounding the *facial vein*, which he ingeniously imagines may cause contractions of the vein, and thereby produce that congestion of the face constituting blushing.

In the cod-fish (*Gadus morrhua*), I have traced nerves from the auricle down upon the venous sinus immediately below it: these formed loops in the walls of the sinus, and appeared to return to the heart. The nerves in question are doubtless a continuation of the cardiac nerves; and, in all probability, bear the same relation to the rhythmical action of this *pulsating* cavity, which the other cardiac nerves do to the cavities of the heart itself.

It is very probable that some such nervous supply is furnished to those parts of the veins of man and mammals, near the heart, in which cardiac muscle is found.

It may, perhaps, be still a question whether the almost complete non-nervous character of veins is absolutely correct, and whether the paucity or tenuity of the nerves, supplied to veins in general, be not the reason why they have as yet eluded observation; for analogy scarcely justifies the idea of organs possessing muscular tissue and still being destitute of nerves. This opinion is strengthened by the fact that arteries, having the same sort of muscularity as veins, though in larger amount, are regularly supplied with nerves.

Comparative structure. — I am not aware of any observations upon the comparative *structure* of veins in birds and reptiles. Those that I have myself made are principally introduced under the heads, *Fenestrated membrane*, *Epithelium*, *&c.*

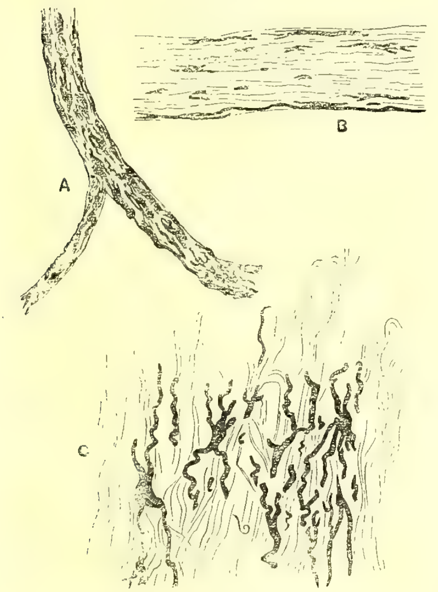
In *Birds*, the venous walls are composed principally of areolar tissue, external to the lining membrane; and I have observed that in the diving-birds, the vena cava posterior is composed almost solely of elastic tissue. There are no muscle-cells in the cerebral veins of birds.

In *Fishes*, the venous parietes appear to be formed of a sort of areolar tissue longitudinally disposed. Embedded in the walls of the veins there is an abundance of *pigment*, which exists in greater quantity in the intercostal veins, and those tributary to the cardinal vein. This pigment is of the variety called by Schwann "stellate pigment cells,"

* In arteries, Weber has never found them in the circular tunic. Burdaeh states that he has found a few.

and consists of branched cells, of a black colour, and various form. The body of the cell is generally some modification of an oval or oblong, and lies with its long axis corresponding to that of the vessel; and from its extremities caudæ project, of every imaginable shape and proportion, of larger size than those which project from its sides, which are few and small. The body of each cell appears to be occupied by its nucleus.

Fig 867.



Veins from Fish exhibiting Pigment cells.

A, vein from muscle of eel (*Anguilla acutirostris*) (*Magnified* 50 *diameters*). B. vein from muscle of sole (*Solea vulgaris*) (*Magnified* 100 *diameters*). C, little mass from the external surface of the cardinal vein of the eel (*Magnified* 200 *diameters.*)

In the accompanying figure, some of these cells are represented from the eel (*Anguilla acutirostris*), and sole (*Solea vulgaris*), which present considerable variety of form. They also vary in the same individual in different situations: in the cardinal vein they are most numerous and aggregated; in smaller veins they are less numerous and more distinct; and in those of minute size, they only occur here and there at considerable intervals, and at the spots where they are placed they occupy nearly the whole face of the vessel.

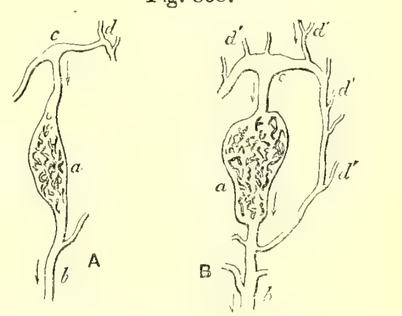
When submitted to high microscopical power, these cells are seen to be mixed up with the tissue of the venous coats, and their thin branched extremities have, in some places, much the aspect of elastic tissue, in the uniformity of their dimensions and their dichotomous divisions.

Caudal venous heart of eel. — Dr. Marshall Hall, in 1831, first figured and described a peculiar pulsating organ which exists in the tail of the eel, calling it by the name of "*caudal heart;*" and he considered it to be a muscular ventricle, by whose contractions the blood is propelled in the vein at the commencement of which it is placed.

Rusconi has differently interpreted this organ, and calls it a *lymphatic heart*, believing that it is perfectly analogous to those pulsating sacs, which are found in certain parts of the lymphatic systems of various reptiles. And certainly the occurrence of a little pulsating organ, having the form, colour, and general aspect of the lymphatic hearts in the frog, situated in the vicinity of the venous system, having an action independent of the systemic heart, and existing in a cold-blooded animal, is, from analogy, enough to suggest the idea that Rusconi's view is the correct one. But this is not confirmed by anatomy, for after repeated and numerous observations of this heart, I am convinced that the original description of it, given by Dr. Hall, is the truth.

The caudal heart is to be found in eels of all sizes, but is best seen in small individuals a few inches in length, on account of their clear skin, and the larger proportional size of the organ in them. It may be seen by holding the eel's tail between the light and the eye of the observer, either with a lens, or without the aid of any magnifying power. It may be conveniently examined with the microscope by wrapping the head of the animal in a wet cloth, and then applying its tail to a slip of glass, and placing it under the field of the instrument; but the extreme restlessness of the little fish sometimes renders it necessary that it should be partially or completely stunned before it can be viewed. The heart is then seen to be

Fig. 868.



Caudal Venous Heart of Eel magnified about 25 *diameters.*

A and B represent two forms. *a*, the heart: *b* cardinal vein; *c* sinus that receives the blood from the capillaries; *d*, minute veins from caudal fin.

placed near the extremity of the cardinal vein, on the hæmal aspect of the caudal vertebræ at the end of the tail. It is of a yellowish colour, chequered more or less with stellate pigment, and of a form varying from a pear-shape to a spindle-shape. (*Fig.* 868.) At the distal extremity it is connected with a small vein, which collects the blood from the capillaries of the tail; at its proximal extremity it is connected with the commencing cardinal vein; or it may be said that on either side is the cardinal vein, and that the heart is a muscular development on the coats of that vessel. The action of this heart appears to be quite independent of the branchial heart; for, as Dr. Hall observes, "whilst the latter beats sixty, the former beats one hundred and sixty times in a minute. It continues for a very long time after the influence of the pulmonic heart is entirely removed."* I have never seen the action of the caudal heart quite so rapid as is described by Dr. Hall: in one individual, partly torpid from cold, it contracted but sixty times in the minute; but when this fish was warmed, the number rose to one hundred and two, — the beats of the branchial heart being less than half the caudal.

The blood, which is deep red, appears to flow into the extreme end of this organ in a *continuous* stream, but is forced out at each contraction from the other aperture in an *interrupted* current. The absence of any regurgitation, at the further end of the heart, would suggest the presence of some valvular apparatus there situate. The jet of blood, sent forward at each contraction, may be beautifully seen by holding up the tail of the eel to the light; it is seen as a regular, *arterial, per-saltum, jet,* passing along the vessel in front of the heart, which, in the intervals of each contraction, is empty: as Dr. Hall expresses it, the blood is "propelled with great velocity, at first with the appearance of successive drops."† This *per saltum* current only exists a short distance, and gradually degenerates into a continuous, venous, stream. When the parts are submitted to low magnifying power, I have observed that at each systole of the heart the veins at the distal extremity of the organ are violently tugged in the longitudinal direction (produced by the shortening of the heart in its contracted state), and this exists as far as several ramifications from the heart (*d′ d′*). A movement in the opposite direction takes place at the diastole, which is doubtless assisted by the elasticity of the vessels restoring them to their former length. This circumstance, moreover, proves the complete continuity of structure of this organ with the small vessels which furnish the blood upon which it contracts.

I have seen this best when the tail has been cut from the body, — the bloodless heart still going on contracting.

I have failed altogether to find any lymphatics going to this pulsating organ; and the facts which I have already adduced, that it receives *blood* from behind, and transmits *it* forwards; the large aggregate quantity of fluid which it propels in a given time; the rhythmical tension of the capillary veins, attached to the distal end, at each contraction, as well as the apparent absence of lymphatics, seem to prove that it is a *blood*, and not a *lymph*, *heart.*

* Hall's *Essay on the Circulation*, p. 172.
† Loc, cit.

II. Physical and Vital Properties. — As it regards the *physical* properties of veins, it may be remarked that their walls are thin as contrasted with arteries of the same calibre, those of the upper extremity being less than those of the lower; they are somewhat looser in texture, especially externally, and more extensile in the transverse direction — are distensible, and when distended they do not readily return to their former dimensions; both circumstances being due, in a great measure, to the general longitudinal direction of their fibres: according to Soemmering the resisting power of veins diminishes with advancing age.

The walls of veins are elastic, though less so than arteries, which pre-eminently exhibit that quality.

The extreme thinness and slight physical resistance of veins is the cause why they collapse when empty.

An empty vein presents very fine longitudinal rugæ on its inner surface.

The tissue of veins is less distinctly yellow than arteries, and frequently is stained of a pinkish colour by the blood in contact with it.

Though their physical properties are, for the most part, of a negative character, they nevertheless possess the property of *tenacity* to a great degree, and are at least as strong as arteries of the same capacity, though the substance of the latter is so much more considerable.

Ligature applied to a vein produces a longitudinal folding of the walls, which is very apparent when the vessel is laid open after it has been tied. An indentation is produced across the inner surface of the vessel at the line of ligature, caused by the complete or partial rupture of its thin inner, longitudinal, fibrous tunic. But the entire thickness of the wall appears to have undergone a partial cut, as though one element of the compound mass of which it is composed had been divided while the rest remained entire; and it would seem probable that a ligature applied tightly around a vein would divide the crisp yellow elastic tissue, while the tenacious white fibrous element, with which it is mixed, would remain entire. This probable explanation I have found, upon microscopical examination, to be correct; the two parts, therefore, of a vein that has been ligatured, are held together by the white fibrous tissue that enters into the constitution of its walls.*

Vital Properties of Veins. — I am not aware of any experiments which have been directed to decide the amount of *sensibility* possessed by veins: it is probably, judging from anatomical grounds, exceedingly low.

As regards *vital contractility*, it has been a matter of dispute whether veins possess that property or not. *Soemmering* held them to possess it in an eminent degree, especially under the influence of chemical stimuli, whilst

* For some beautiful illustrations of ligatured veins, I would refer to Cooper and Travers's Surgical Essays, vol. i. plate 12.

Haller * denies that they are endowed with irritability. It is now placed beyond all question that veins are endowed with *vital contractility*, and that it exists in them in two distinct and entirely separate forms — first, as a *rhythmical* contraction, similar to what occurs in the cardiac cavities; and secondly, as that peculiar slow and prolonged contraction which is known as *tonicity*, and which in so striking a degree exists, and exists alone, in arteries, — the former occurring in a small portion of the venous track, the latter pervading nearly the entire venous system. To the establishment of this last physiological fact, we are mainly indebted to Professor Kölliker.

Venous rythmical contraction in man and mammalia generally occurs only in the immediate neighbourhood of the heart, but in cold-blooded animals it extends a considerable distance along the venous trunks. Flourens † was the first to describe it in the frog, where it has frequently been since witnessed; and Müller has observed that the venous trunks of the frog continue to contract even after the removal of the heart and the auricle.

Nysten has witnessed contraction of the upper part of the vena cava in fish; and Wedemeyer has observed the same in other cold-blooded animals. According to Müller the rhythm of the veins in frogs occurs just previous to that of the auricle, and the rhythm of the auricle before that of the ventricle, and the rhythm of the aortic bulb follows the ventricular: there are four successive contractions, of which that of the veins is the first.

In mammalia the venous contraction is almost synchronous with the auricular. I have frequently witnessed it in vivisect animals—rabbits, kittens, &c.; and it exists in the pulmonary veins as well as in the cavæ. It is only in the immediate neighbourhood of the auricles that the veins contract, doubtless just so far as the cardiac muscle is prolonged into the venous tissues. The rhythm appears to commence upon the vein and pass forward upon the auricle. This vascular rhythm, existing in a high degree in the lower vertebrata, and diminishing in the higher, would appear, in man, to be the last remnant of the tubular heart seen in the invertebrata.

It appears very probable that the contraction of the veins close to the auricles may be of assistance in the economy of the heart's action. If it be recollected that the auriculo-venous orifices are not guarded by valvular apparatus, it will be difficult to explain how, when the auricles contract, the blood is prevented from flowing back into the patent veins: may not this be prevented to a certain extent by the contraction of the veins, which thus constitute a sort of sphincter? This *rhythmical action* of the veins must in no way be confounded with that peculiar *venous pulsation* which exists in certain forms of disease. *Venous tonicity* has lately been established by Kölliker *, and his physiological experiments have been based upon and fortified by the most conclusive anatomical discovery —viz. the demonstration of unstriped muscular fibre in the walls of veins.

Professor Kölliker's experiments were made upon the veins of a leg immediately after amputation; and the agent of muscular excitation was an electromagnetic apparatus. "The vena saphena minor was touched in the fossa poplitea, on the lower part of the leg and on the foot; the vena saphena magna on the lower part of the leg and dorsum pedis. A few seconds after the application of the wire, contraction took place; at the end of a minute the parts touched contracted so much, that the blood that they contained in large quantities was pressed out, until the vessel had the appearance of a white cord. On smaller veins of the skin, the effect was not so rapid or so powerful."

"Three applications of the wire had no effect on the vena poplitea, but it was already very flaccid and empty before the experiment. The vena tibialis postica was empty by contraction in a minute."

The irritability endured in the veins for an hour and fifteen minutes, being somewhat longer than in the arteries and lymphatics, and shorter than in the muscles.

This contractile power in veins is of that peculiar character which has long been known to exist in arteries: it is slow, gradual, and persistent, and by it the vessel is braced up and set at a given calibre. This contractility, combined with the elasticity of the vessel's walls, is the antagonist to the distending force of the blood within the vessel.

I have frequently noticed in animals examined during life, that the large venous trunks are of greater calibre than when viewed after death: that whilst the blood flows on through the vessel, it is distended to a larger size than when from exudation and other causes the quantity of distending fluid is diminished; just as at each jet of blood passing through an artery the tube is distended, in opposition to its contracted state after death,—the explanation being undoubtedly this, that immediately after death the vein-muscle becomes affected with cadaveric rigidity, and this being unopposed by the distending blood, contracts the vessel to a calibre less than that which it could hold whilst the contraction was opposed by the distending force of the circulating fluid. The same thing occurs more distinctly in arteries, and, whilst the rigor mortis remains in activity, forms a powerful opponent to injections.

III. General Remarks upon Veins — Origin; Course; Anastomoses; Plexuses, &c. — General considerations of veins are to be made principally in relation to arte-

* Sec. Mém. sur les part. sensibles et irritables: and Elem. Phys. lib. ii. p. 126. and lib. vi. p. 125.

† In Annales des Sciences Natur. tom. xxviii. p. 65.

* Kölliker and Siebold's Zeitschrift. 1849.

ries, in contrast with which the characteristics of the former are most conspicuous.

The *general*, the *pulmonary*, and the *portal* venous systems may be looked upon as the roots of a tree, the trunks of which would correspond with the auricles and the porta; or they may be viewed as three cones, the bases of which are the capillaries of each system, and the apices, the auricles, and the porta. In either view, the veins are to be examined, in their track intermediate between these two points, as to their *number*, *size*, *relation*, and modes of *dividing* and *junction*. These observations will be carried solely as far as they refer to the general circulation, and that principally as it affects the human subject; the pulmonary and the portal systems being more properly considered in conjunction with those viscera with which they are connected.

The venous system is far more extensive than the arterial, both as it regards *size* and *number* of vessels.

Attempts have been made by different anatomists to estimate the relative size of arteries and veins, though it is difficult to see upon what data any thing like an exact calculation can be based; nevertheless, Sauvages states the capacity of veins, as compared with arteries, to be as *nine* to *four*, Haller as *two* to *one*, and Borelli as *four* to *one*. Though it may be impossible to say which of these is the true estimate, it is obvious that the disparity between the two sets of vessels is very great. In the extremities and head, indeed everywhere but in the viscera, the veins form two distinct sets, the superficial, subcutaneous, veins, and the deep veins accompanying the arteries. These latter, which are called *satellite* veins (*venæ comites*), are almost always double—two veins accompanying each artery of the same name. " This rule, however, has some exceptions; in fact there is only one accompanying vein for most of the great arterial trunks, and even for some arteries of moderate size; lastly, in some few instances there is but one vein to two arteries. Thus, there is only one superior and one inferior mesenteric, one renal, and one external iliac, vein, each of which corresponds to the artery of the same name; but there is only one umbilical vein to two umbilical arteries, and there are several suprarenal arteries, but only one suprarenal vein." (*Cruveilhier.*) These exceptions, however, are not sufficiently numerous to alter the diffuse and branching character of veins. The following apposite quotation upon this head is from Meckel:—" It is a universal law with veins, that the branches or ramifications are larger in comparison with the trunks than in the arterial system; the veins of a part, or even of the whole body, never uniting themselves to so small a number of stems as those out of which the arteries take their origin. The aorta and pulmonary artery originate as single stems out of the respective cavities of the heart; the systemic veins, on the contrary, terminate in three trunks, the superior and inferior cavæ and the coronary vein; moreover, the superior cava receives, but just before its entrance into the heart, a fourth trunk — the azygos vein. The pulmonary veins terminate in four, five, or even six trunks into the left auricle. Again, in the extremities,—take the arm, for instance,— where there is but a single artery, there are four considerable venous trunks. Thus division is the character of the arrangement of the veins; contratension that of the arrangement of the arteries." (Meckel, Handbuch der menschlichen Anatomie, Band i. S. 201.)

Origin of Veins.—Veins originate, almost without exception, by the capillaries uniting — increasing in size, and diminishing in number. This fact has been known, and all but universally received, since the days of Malpighi, who (in 1661) demonstrated, by microscopical research, that portion of Harvey's system of the circulation which had not been displayed,—the passage of the blood intermediately between the arteries and veins,— the *capillaries*,—and thereby explained the *origin* of the veins. That veins originate *only* by capillaries has also been generally admitted; but Haller has described *absorbent veins* as arising from all free surfaces; and Cruveilhier speaks of veins commencing with open mouths on the surface of all mucous membranes; opinions long since refuted. There appear, however, to be some exceptions to this general rule of capillary origin of veins. Thus, the veins which return the blood from certain portions of erectile tissue would seem to commence as little venous caverns or sacs, into which blood is poured by arteries of a size much above capillary vessels. (*Valentin: Müller.*)

Mr. Paget has recently pointed out another mode of venous origin as occurring in the wing of the bat (*Vespertilio*), where arteries of comparatively considerable size pass at once into veins without intermediate capillaries. Mr. Paget observes: " Very generally the arteries of the second and third order of branches pass into veins of corresponding size without any intermedium of capillaries. The capillaries are rather in the position of offsets from the continuous channels of arterial and venous loops, than in their more ordinary relation as intermediate canals leading from arteries to veins."* Further research, especially in comparative anatomy, will probably exhibit other instances of peculiar venous origin.

Course, Anastomoses, Plexuses, &c. of Veins. — In travelling from their commencement to their termination, veins follow very various courses, the most marked differences indicating a division into those which accompany their corresponding arteries, and those which pursue an independent course; a division which corresponds, with a few exceptions, to the deep and the superficial veins.

In commencing, the veins form networks of

* Lectures on Inflammation, by James Paget, F.R.C.S., in Medical Gazette, vol. xlv. p. 968.

vessels, which unite and reunite till they form venous trunks, which then take a more or less direct route to the heart.

The *deep* veins accompany the corresponding arteries, and pursue the same course as these latter vessels, having similar relations with the bones, muscles, nerves, and fasciæ: they are moreover surrounded by the same sheath of condensed areolar tissue as the arteries. It is remarkable, as has been observed by Cruveilhier, that the relative position of the two kinds of vessels, although constant, does not seem to follow any general rule; all attempts to ascertain any law by which the relations of the veins with the arteries are regulated have been unsuccessful.

In some situations deep veins do not take the same course as the corresponding arteries. This is the case with those of the nervous system (the *cranial sinuses* and *spinal veins*), the hepatic vein, the ophthalmic vein, the azygos vein, &c.

The *superficial* or *subcutaneous* veins follow an independent course, as respects arteries, and accompany the cutaneous nerves and lymphatics in the interval between the muscular aponeuroses and the skin.

The *anastomoses* of veins, and the *plexuses* formed thereby, are abundant and elaborate. The inosculations are more numerous than those of arteries, and occur by means of much larger vessels. They take place "by direct inosculation, by lateral, transverse, or oblique, communications, and anastomoses by convergence, which are found in every situation and with all conceivable varieties. The branches of the veins form lozenge-shaped meshes; and both the trunks and the branches communicate freely with each other; that is to say, the superficial with the deep set, the veins of the superficial set and those of the deep set amongst each other, and the vena cava superior with the vena cava inferior: so that we may say that the whole venous system forms one vascular network; and it is by these free communications that such obstacles as impede or completely intercept the course of the blood in a given part are rendered incapable of stopping it altogether." (*Cruveilhier.*)

The anastomoses are so numerous and complete, that it is almost impossible to intercept the venous circulation by the interruption even of vessels of considerable size: if even the *superior cava* with the venæ *innominatæ* be interrupted, the blood will be returned — finding its way back to the heart by the anastomoses of the internal mammary, the acromio-thoracic veins, &c. with the intercostal, azygos, and epigastric veins — so taking the blood back by means of the inferior cava. An obstruction of the inferior cava is compensated for by the same set of vessels, the blood going then in the other direction.* Obstruction to the portal circulation does not absolutely stop the blood: inosculations occur between the portal and general systems of veins in the hæmorrhoidal plexus sufficient to maintain the blood-current.

* See Morbid Anatomy.

These are some of the *special* examples of anastomoses; the *general* method of inosculation also requires some explanation. For example, a vein arises in conjunction with another collateral vein, or takes its origin from the latter, and after having pursued a course of various length, again joins the principal vein. Instances of this may be seen in the various veins of the extremities.

Fig. 869.

Venæ mites Spermaticæ. (*after Breschet.*)

A venous trunk may divide into two of equal size, which separate at a very acute angle, and, after an elliptical interval, again unite into one. Such may frequently be observed in the saphœna.

Cross anastomoses, by means of large veins uniting those on the opposite sides of the body, are not unfrequent. Such are the circular sinus and the basilar sinus, in the skull, the azygos, and the intercostal veins, &c. A vein, just before its junction with the trunk to which it is tributary, divides into two, and joins at different parts — an occasional variety of the frontal vein.

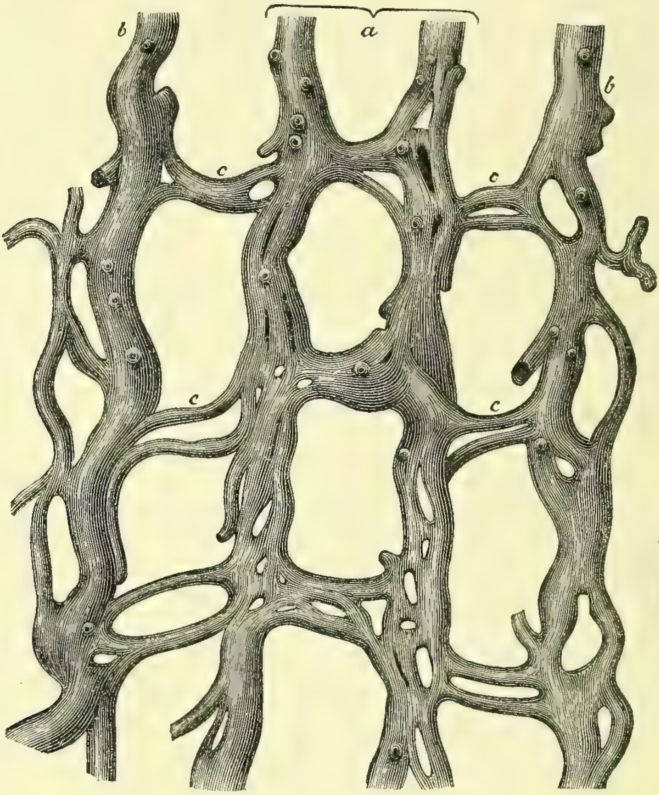
The *plexuses* of veins are merely a high degree of anastomosis: they are not subservient to any laws in their formation and arrangement, or susceptible of any systematic division; and will probably be best understood by describing and figuring a few of the most characteristic.

The simplest and most primitive form of plexus is that which is produced by the inosculations and joinings of *two venæ comites* around and across an artery. Such is exhibited in the accompanying figure: the anastomoses are so numerous, that it is difficult to tell in parts whether they are to be considered as two vessels, or as one, with frequent trivial interruptions of cavity: at some points they run a considerable distance without conjunction, leaving an elongated elliptical interval; and at other points their confluence is so great that the intervals are reduced to small circular apertures on the face of one broad vein.

A coarser and more complicated form of plexus is exhibited in the subcutaneous system of veins, in the production of which several venous trunks combine, and by their lateral branchings and confluxes produce diamond-shaped, rhomboidal, and triangular interspaces: — these anastomoses being all on the same plane, excepting at a few points here and there where a small channel dips down to the deep veins. Such plexuses may be seen on the dorsum of the hand and foot.

But the most elaborate and complex of all the plexuses in the human* subject are those formed around, about, and within, the spinal canal: they are composed of numerous trunks, which unite, divide, and re-

Fig. 870.



Plexuses connected with the Spinal Canal.

a, the great anterior spinal veins (the "*grandes veines rachidiennes longitudinales antérieures*" of Breschet); *b*, ascending lumbar veins (the "*veines lombaires ascendantes*" of Breschet); *c*, veins uniting the above-mentioned, through the intervertebral foramina (after Breschet).

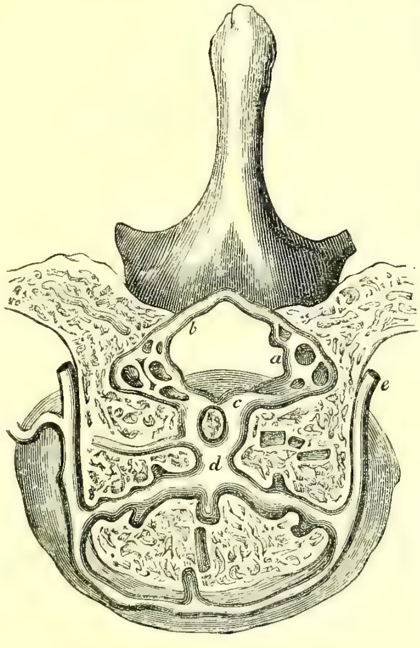
unite, at every possible point, and in all conceivable modes, by branches of all sizes, lengths, and shapes, and leave intervals presenting forms of endless variety. A portion of these plexuses, seen in the accompanying figure, from Breschet's work on the veins, conveys a better idea of them than any lengthened description.

The *diploic* plexuses are the net-works of veins which exist in and among the cancellated tissue of the bones. In the flat bones of the cranium, at the period of adult life, they form large irregular meshes, by the meanderings of large, irregular, ampullated, veins. These vessels are very unequal in size, are subject to dilatations, and frequently end in *culs-de-sac*. They are well represented in *figs*. 187. and 188. Vol. I. But the most remarkable peculiarity in these plexuses, is the change they undergo during osseous development. In early fœtal life, when ossification commences the cranial bones consist of stellæ of numerous ossific rays, the interspaces between them being occupied by hosts of small, almost straight, radiating, veins: these veins are not covered in by osseous structure, but are exposed on both surfaces of the bone (*fig*. 872.); they then gradually become tortuous, and fuse into one another, so as to diminish in number, and lose much of their radiating character; and after a time they become covered by a thin plate of bone on either surface. The process of fusion and dilatation of the veins still goes on during life, and ultmately leaves the diploic plexus, consisting of a few large vessels. Diploic vessels exist in all cancellated bone in various plexiform combinations. In the loose texture

* In birds the intra-spinal plexuses are so large and dense that it is with difficulty that the anatomist can make out that they are not extravasations.

of the bodies of the vertebræ remarkable plexuses exist. (*Fig.* 871.)

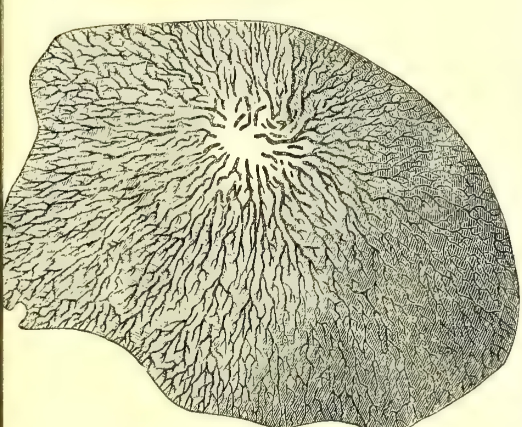
Fig. 871.



Diploic Veins in a Vertebra.

a, great anterior spinal veins; *b*, posterior spinal veins; *c*, transverse branches; *d*, venæ basis vertebrarum; *e*, vein on the surface of the body of the vertebra. (*After Breschet.*)

Fig. 872.



Parietal Bone of Fœtus at nine months, exhibiting the veins. (*After Breschet.*)

IV. Function of Veins. — In function veins may be considered as having a triple office: they are passive organs of circulation; they are diverticula or reservoirs for blood; and they are agents of absorption.

Circulation in the veins consists of the passive and equable transmission of blood along their tubes. "When we consider the great size of the veins, compared with the arteries, we must conclude that the blood flows but slowly in the venous system; that, from the narrowness of the trunks of the veins near the heart, the blood must be accelerated as it approaches the heart; and that receiving the impulse from the ventricle, it must take a rapid course through the arteries, until, again approaching the extreme branches of the arteries, and passing into the veins, its motion becomes more languid and slow. In youth, as the size of the veins is not in so great a proportion to the arteries as in advanced life, the blood must be in more rapid circulation: but in old age, owing to the largeness of the veins and the accumulation of blood in them, it moves slowly through the venous system, and is almost stagnant in the dilated veins and in the sinuses.

"There is no pulsation to be observed in the veins, but what they receive from contiguous arteries. There is no pulsation in the veins because they are removed from the heart; because they do not receive the shock of the heart's action in their trunk, but only by their widely-spread branches; because the contraction of the heart and of the arteries so alternate with each other, as to keep up a perpetual and uniform stream of blood into the veins." (Sir C. Bell's Anatomy, vol. ii. p. 284.)

As *diverticula* and *reservoirs* of blood the veins must be considered as performing a most important service in the œconomy of the circulation. There are numerous circumstances both in health and disease which either temporarily or permanently disturb the balance of the circulation, and thereby displace and choke up large quantities of blood; and, were it not for the reservoirs, diverticula, and lateral compensating channels, which are afforded by large, bulging, and dilatable veins, by the enormous area of the common venous cavity, and by the numerous and elaborate inosculations and plexuses which these vessels every where exhibit, such interruptions might lead to consequences, permanent, irremediable and destructive.

The whole subcutaneous system of veins must be looked upon as a series of compensatory channels. The cavities of the deep veins are quite sufficient to return the blood that is sent to them by vessels of smaller aggregate calibre. But during muscular exertion, &c., these deep vessels are impeded by pressure, and then the blood finds a collateral route by means of the subcutaneous veins. So again, when from cold, or other causes, the skin-muscle contracts and presses on the cutaneous veins they are more or less emptied, and their office is resumed by the deep veins: they thus keep up a mutual reciprocation of function.

The large internal veins of the body; the dilatations of the veins at the base of the brain; the large amount of veins in the parenchymatous viscera; the venous plexuses of the spinal canal, together with the venous cells and tubes in the cancellated tissue of all bones, form a series of diverticula and reservoirs, equal to all emergencies*, where the blood may slowly flow, or recede, or stagnate. But the most striking examples of venous reservoirs are furnished by comparative anatomy. All those animals which have diving habits subject themselves to peculiar disturbance of circulation. The prolonged stoppage of respiration, but still more the immense pressure of water to which they are exposed, when deeply submerged, mechanically empties all the superficial veins and produces much deep-seated and visceral congestion. This is compensated for by a special arrangement. In diving birds there is great dilatation of the posterior vena cava. In the Grebes and Divers (*Podiceps* and *Colymbus*) the posterior cava is largely dilated in the liver and below, extending to opposite the kidneys. In the Cetacea, which are subject to the same influence, enormous dilatable venous plexuses, placed within the abdominal cavity, perform the same office.

Venous absorption probably occurs wherever veins exist, but especially in the alimentary canal, where, in conjunction with the lacteals, they perform the important office of extracting from the food the different materials which enter the circulation and nourish the various tissues of the body.

It is not my intention to enter upon any of the elaborate arguments or disquisitions on the evidence of venous absorption. I shall content myself with a brief summary of the most important salient points.

That absorption by the veins takes place independently of the lacteals has been proved by a series of conclusive experiments conducted by Tiedemann and Gmelin†, who administered to a number of animals various substances of distinct and easily recognisable physical and chemical properties, and afterwards analysed the venous blood, the secretions, and the chyle. Substances having deep colours, such as cochineal, indigo, litmus, gamboge; substances having strong odours — turpentine, assafœtida, garlic, musk — and saline substances, such as sulphate of iron, chloride of barium, ferro-cyanide and sulpho-cyanide of potassium, were all in turn submitted to experiment. Almost all of these matters were found in the venous blood, several of them in the urine, and a few only of the latter (the saline substances) in the chyle. Therefore it appears that absorption did take place, in many instances, independently of the lacteals, and by the veins. This conclusion is fortified by other experiments conveying both positive and negative evidence, which have been performed by Majendie, Blake, Delille, Segalas, &c.

Majendie and Delille in conjunction performed the following experiment. They severed all the parts of the posterior extremity of a dog, excepting the artery and vein by which the circulation of the limb was kept up. They then introduced some upas poison into the foot; and in ten minutes the animal died. It cannot be imagined here that the lymphatics absorbed the poison, as they were divided; but it may be objected that the matter was mechanically introduced into the divided extremities of the vessels in the wound. This difficulty has been overcome in another experiment devised by Majendie. He found that death was caused by the introduction of nux vomica into the intestine of an animal in which the lacteals had been tied, where the veins, by which alone absorption could here take place, remained entire. An experiment exactly the reverse of the last was performed by Segalas, which completely bore out the idea of venous absorption. Instead of tying the lacteals and leaving the veins untied, Segalas tied the veins, the lacteals remaining unimpaired. The result was, that when poison was applied to the intestine, no absorption took place, and no result followed. It was further found by Mr. Blake, that ligature of the vena porta prevented the action of poisons introduced into the stomach.

V. Development of Veins. — Are the veins, large and small, originally developed as capillaries, the succeeding changes by which their texture and size are modified taking place subsequently to their being permeable sanguiferous channels? Whether this is entirely the case is doubtful: that it is so to some extent is certain; and therefore the development of veins would involve two considerations — first, the development of capillaries, and secondly, those after-changes by which the vessels cease to be capillaries, and become, in texture and volume, true veins.

The arguments in favour of the view that veins are developed primarily as capillaries, are — that veins, arteries, and capillaries constitute one continuous system, which renders a community of development antecedently probable; that arteries and veins are so similar in structure as evidently to possess a common development, which heightens the probability of their development being the same as their connecting link; that the part possessed by capillaries — basement membrane — is that which we see in other parts capable of giving rise to fresh structures; that we see all stages between the largest veins and capillaries filled up without a gap; that structures which in an early stage are furnished only with capillaries, and vessels a little removed from them, are found shortly

* Not literally equal to all emergencies: the great deep-seated congestion caused in the cold stage of an ague-fit has ruptured the vena cava: the same has occurred in violent muscular exertion.

† Versuche über d. Wege auf welchem Substanzen aus dem Magen u. Darmkanal ins Blut gelangen. Heidelberg. 1820.

to contain veins, and that the venous textures become more strongly marked as the parts become more mature; and that veins but little removed in size from capillaries, differ from them by the addition of structures exactly similar in nature to those which larger veins possess in a greater amount.

The development of capillaries has been observed, principally, by Schwann * in the tails of young tadpoles, and the germinal membrane of an incubated hen's egg, by Kölliker †, in the tails of batrachian larvæ generally, and by Paget ‡ in the fœtal membranes of sheep. Their accounts, which my own observations on the tails of batrachian larvæ entirely confirm, all substantially agree.

On subjecting the tail of a very young tadpole to microscopical observation, and viewing it with an object glass of a quarter of an inch focal distance, it will be seen that the vessels possess all the characteristics of very fine capillaries, that is, they possess a delicate, perfectly homogeneous membrane, with nuclei adhering here and there to its internal surface. The two great arterial and venous trunks are elongated posteriorly, as the larvæ grow, by throwing out prolongations, which, by joining the embryonic cells accumulated about the extremity of the chorda dorsalis, inosculate with them so as to form a continuous cavity. The first lateral vessels of the tail, which have the form of simple arcs going from artery to vein, are formed by the junction of prolongations, from the caudal artery and vein, with certain elongated or stellate cells in the substance of the tail. From these vessels, which constitute what may be called the primary arches, are thrown out projections which, by inosculating in an exactly similar way with neighbouring stellate cells, form secondary capillary arches; and thus the capillary network continually extends itself in proportion as the tail gets longer and broader, and at the same time becomes more dense by the formation of new vessels between the primitive meshes.

Such are the general appearances seen in the tail of any of the batrachian larvæ. These, however, Schwann does not consider so conclusive as the appearances in the germinal membrane of a hen's egg. He says that when the germinal membrane of a hen's egg which has been subjected to thirty-six hours' incubation, is placed under the microscope, and the area pellucida examined with a magnifying power of 450, the capillary vessels are readily distinguished in it. In some situations they are perfect, and connected with the larger vessel, some are of irregular calibre, having bulgings here and there where two or three channels meet, the intervening portions varying in size from that of a fibre of yellow fibrous tissue to the full capillary diameter, and permeable to blood or not.

* Microscopical Researches, translated for the Sydenham Society, by Henry Smith.
† Annales des Sciences Naturelles. August, 1846.
‡ Supplement to Müller's Elements of Physiology, by Drs. Baly and Kirkes.

In addition to these capillaries, which form a network of channels of irregular calibre, and give off blind branches, some separate irregular corpuscles are seen which are not connected with the vascular network. These bodies send off blind processes, of various forms, in different directions; in other words, they are stellate cells. They have a reddish-yellow colour, like that of the capillaries of bone, which circumstance alone would be sufficient to make it probable that they are the primary cells of capillaries in process of formation; and this probability becomes a certainty when we perceive that some of these same stellate cells are already connected with the true capillaries, forming with them a common cavity. This is Schwann's description. Of its correctness I cannot speak from my own observation, but of the correctness and extreme truthfulness of Kölliker's account of the same process in the tails of young batrachia I can, from my own observations, confidently speak: indeed he has left nothing to be added.

Morbid Anatomy of Veins.

Veins are subject to a variety of morbid changes, which are naturally incident to blood vessels of their particular organisation and functions, occasioning a remarkable contrast in their pathology with that of arteries.

Thus veins are much more subject to diffuse inflammation than arteries, and the products of their inflammation being carried in the blood to the heart, are conveyed all over the body; they moreover offer peculiar facilities for the introduction of morbid materials into the circulation, and from both these circumstances wide-spread and diffuse disease is the result — conditions which have no parallel as the consequence of arterial disease. Again, an injury to a vein, such as a punctured wound, is followed by cicatrization; and any dilatation of its tube interferes only partially with its functions; whereas in an artery, from the vigorous and pulsating character of the circulation in it, a wound is only to be healed by obliteration of the vessel, and any dilatation of it causes an aneurism — a progressive and destructive disease.

From the time of Hippocrates, some of the diseases of veins — varix and hæmorrhoids — have been recognised; but it was not till John Hunter, in 1793, published his paper on the diseases of veins in the "Transactions of a Society for the Improvement of Medical and Chirurgical Knowledge," that any light was thrown upon that most important of these diseases — *phlebitis.*

Since then the subject has received a large share of attention at the hands of some of our most distinguished pathologists: and Hodgson, Travers, Breschet, Bovillaud, Ribers, Arnott, Lee, and hosts of others, have all added their quota towards its elucidation.

The diseases of veins divide themselves into *phlebitis*, with which may be considered the effects of *wounds* and *ligatures; varix* and *hæmorrhoids; rupture; disease of valves*; *phlebolites; calcareous degeneration; fatty tumours; entozoa.*

Phlebitis. — Phlebitis may be conveniently divided into plastic and suppurative. They, however, frequently exist together, are produced by the same cause, or give rise to each other.

Veins possess peculiar facilities for the production of certain of their diseases, especially inflammation of their lining membrane, caused by the introduction of morbid materials into their cavities; which is a very general cause of the disease now under consideration. They are peculiarly subject to being opened, on account of their superficial position, and their being submitted to the surgical operation of venesection; and it must be remembered how large a superficies of the venous cavity is exposed at every parturition to the contact of those fluids which are secreted in the healing of the placental wound. The veins situated in the osseous tissues present peculiar facilities for the introduction of morbid matters into the circulation, on account of the patency of their cut extremities, caused by the adhesion of their walls to the unyielding tissue in which they are embedded. Again, the direction ofe th current of the circulation towards the heart, is not likely to expel any materials that are introduced into the vein, but would rather tend to carry them on into the mass of the circulating fluid.

The absorbing function of veins is often referred to as a cause of the introduction of morbid matters into the circulation, and this especially as it regards *pus*, but it cannot be strictly said that pus is absorbed in cases of purulent phlebitis; and I apprehend that the distinction laid down by Hunter*, on this point, is perfectly correct. It appears to me impossible for any one acquainted with the structure of the coats of blood-vessels, and the anatomy of a pus-cell, to imagine that pus, *as such*, can be introduced within a vein by any process analogous to absorption. It is true that pus may enter a vein *bodily*, and *as pus;* and it is equally true that pus may be absorbed; but the former is by introduction through some lesion in the vessel's walls, and in the latter the fluid is in some way altered before it can pass through the tunics of the vein, if, indeed, a vein be here the agent of absorption. When pus is absorbed, as from a bubo, or in empyema, it is attended with a different series of symptoms and consequences from those which arise when it is introduced bodily, and pus is, in these cases, not to be found in the veins; and it must be remembered that all the circumstances — *a wound secreting pus and an open vein*, or, what is tantamount to the same, *such inflammation of a vein as leads to secretion of pus in its cavity,* — are uniformly present where the characteristic results of phlebitis occur. The same thing is imitated by injecting pus into the veins—with like results.

Plastic phlebitis bears the same relation to suppurative, that the two forms of inflammation hold relatively to other organs. Plastic phlebitis indicates a form of disease of milder character, and consummated with results of less severity. Suppurative phlebitis is more or less mixed up with the plastic form, and is generally secondary to it.

When a vein undergoes inflammation, the affected portion throughout its entire thickness becomes of a diffused red, which is not, at this stage, to be distinguished from the red stain produced by contact of the blood, observable, under certain circumstances, in both arteries and veins; this fades at the edges of the inflamed portion. As the disease advances, the part becomes irregularly mottled of all shades, from purple to the natural colour of the part; with this appears, in the areolar tissue of the veins, an effusion of sanious serum. The effusion does not end in a serous exudation; but, as the disease progresses, a plastic effusion is exhibited, not only in the tissue of the vein, but also within its cavity. Whether or not the previously developed serous effusion also escapes in part upon the free surface of the lining membrane of the vein, is not easily determined, but in the stage now under consideration it probably does so, as in other serous inflammation. At all events, at or immediately after the time when such effusion occurs, the tube of the vein becomes blocked up with a coagulum of blood: this does not occur at once, but progressively, beginning by the deposition of fibrine upon the inflamed surface, which deposition is increased by successive layers, the original being for the most part the most compact, until the entire tube is blocked up. That part of this fibrinous product is formed by the serous lining of the veins, — secreted from the vasa vasorum, — is proved beyond all question by the experiments of Gendrin and Hope. Gendrin found that, by securing a portion of a vein between two ligatures and removing all the blood it contained, upon injecting some irritating substance into it, plastic lymph was exuded in sufficient quantity to fill the cavity of the insulated portion.* In this experiment the fibrinous matter was clearly *true plastic lymph,* in all respects similar to the plastic effusion in other serous cavities. Again, the experiments of Dr. Hope, in which, by mechanical irritation, he produced warty excrescences on the valve of the aorta, support the view I have taken. There are many points in the formation of these coagula in veins which are remarkable. That they do, as already stated, consist both of lymph-exudation and coagulated blood is more than probable. But what determines the coagulation of the blood in plastic phlebitis, is less obvious. That the inherent power of coagulation, which the blood in itself possesses, is the cause, is not saying enough. There are

* On the Blood, p. 360.

* The experiments were originally performed upon arteries, but were repeated upon veins with similar results. Dr. Hope's were upon the aorta near the heart: however, they prove the same fact —effusion of lymph on the lining of the vascular cavity.

certain conditions which must occur before coagulation can develop itself. While the blood, itself in a state of health, remains in contact with the lining membrane of healthy blood vessels, coagulation is impossible; but under certain conditions of disease the blood loses its fluidity, and these conditions may either consist in some abnormality of the vessel's walls, or in some foreign matters becoming mixed with the blood, — the former influence being passive, and the latter an active agent in producing or hastening coagulation.

I would here urge the doctrine that the vascular cavity, — the hollows of all the tubular vessels (veins, arteries, and lymphatics), together with the ventricles and auricles of the heart, — constitutes a true serous shut sac, much complicated in form and modified by its peculiar functions, it is true; but possessing the same anatomical elements, — an epithelial pavement placed upon a sheet of limitary tissue, on the other side of which is situated a nutrient vascular system. I would here urge this view, because it applies with much force to certain questions in venous pathology, and to few more so than the one under consideration, where arguments by analogy are a desideratum. The lining membrane of the veins then is a serous membrane. On the surface of other serous membranes — pleura, pericardium, &c. —plastic effusion consists of sheets of lymph, and a certain amount of serum. By analogy we, *à priori*, conclude that lymph is effused in inflammation on the lining surface of the veins, and this the experiments of Gendrin and Hope have established by indisputable proof. That the inflammatory product consists partly of serum as well as lymph is supported by analogy alone; but if admitted would explain the coagulation of the blood to complete the clot, which is known to be so much facilitated by the admixture of foreign or abnormal secretions. Whatever may be the opinion of the formation of the coagulum, its characters are these: — it consists of concentric laminæ, brownish, yellowish, or white, of which the central are the darkest and softest; and sometimes the centre is nearly fluid blood. The density of the entire clot is subject to much variety. The coagulum is moulded to the cavity of the vein, and sometimes present the exact impression of the valves. Mr. Arnott has made an interesting observation with respect to the coagulum, that it extends along the affected vein usually to the next collateral branch, and there abruptly ceases. The true explanation of this circumstance is doubtless that given by Mr. Henry Lee.* "When any portion of a vein is obstructed, the blood is kept at rest between the obstruction and the next collateral branch; and, if disposed to coagulate, there is nothing to interfere with such an action. But the case is different as soon as one vein opens into another. A fresh current of blood is then continually sweeping the orifice of the obstructed vessel; and even although the blood at this point should have a tendency to coagulate, it is carried on in the course of the circulation, before it can adhere to the sides of the unobstructed vein."

The coagulum thus extends towards the heart, beyond the limits of the inflamed portion, having a mere mechanical boundary. It extends also at the distal end, but here it becomes gradually attenuated: it often ramifies into many branches and subdivisions of the veins that are tributary to the one obstructed, especially where they are not relieved by collateral anastomoses. At those points where inflammation has not occurred, and the coagulation has been favoured by mechanical circumstances simply, the clot scarcely adheres to the lining membrane of the vein.

But the plastic product is not always in the form of a plug, moulded to the cavity of the vein: it sometimes consists of shreds or fringes of lymph, firmly attached to the lining of the vein, and hanging into its cavity, either from the walls or in festoons from the valves.*

The walls of the vein, at the same time, undergo change, indicative of the same inflammatory phenomena, which consists mainly in interstitial plastic deposit among the areolar tissue of the tunics.

"So soon as a fibrinous plug of this description is established, the red and violet speckled colouring abates in intensity, and the internal membrane, losing its smoothness and polish, assumes a dull velvety or slightly puckered appearance. The external membrane appears thickened, turgid, and soon becomes adherent to the cellular tissue, which in its turn has been rendered firmer and paler from the effusion of plastic lymph. Both membranes are still readily distinguishable, and even separable, from each other; the consistency of their texture is however impaired, and they are easily torn. In this state of things a vein, when cut asunder, does not collapse, even after the plug has been removed; but, on the contrary, its calibre remains open like that of an artery. This is more than ever the case when the surrounding cellular texture has acquired firmness by the condensation of the inflammatory product infused into it, or when it puts on a brawn-like character, and intimately coalesces with the external membrane of the vessel.†

These phænomena may occur in veins of any size; and to any extent in any particular set of vessels. They occasion obstruction of the circulation in all vessels tributary to the one affected. Of such a condition Phlegmasia alba dolens may be instanced as an example.

As regards the cause of plastic phlebitis, or, indeed, of venous inflammation in general, it may be the result either of spontaneous action, or the circulation of poisoned blood— the latter being infinitely the most common

* On Phlebitis and Purulent Deposits, by Henry Lee, Lond. 1850, p. 23.

* See Cooper and Travers's Essays, Lond. 1818, part i. plate 10.

† Hasse's Pathological Anatomy, Sydenham Society's translation, Lond. 1846, p. 13.

cause. In the latter case the inflammation of the vein is excited by contact of a coagulum of vitiated blood with the lining of the vessel. But the veins may, as well as other tissues and organs, be the seat of spontaneous inflammation. This is frequent in some forms of varix; especially in hæmorrhoids, and usually, though not always, leads to the coagulation of the contained blood. I have seen acute inflammation of a varicose saphena causing much interstitial plastic deposit, in which no coagulum formed in the interior of the vessel, whose canal was quite pervious.

Suppurative Phlebitis.—When phlebitis leads to suppuration, it is generally, I believe always, accompanied by plastic effusion also.

The question of pus formation within veins is one of great importance and interest, and difficult of solution. In a great proportion of examples, purulent phlebitis is originally lighted up by the mechanical introduction of pus into the veins. In some few cases the pus would seem to originate within the vein, either from an ulceration of the inner surface, or perhaps it is secreted free on the unbroken lining membrane. One very remarkable point is the enormous multiplication of the pus within the vein. No absorption, or mechanical introduction, can at all explain the immense increase; and it is obvious that there exists within the vessel some source of this pus generation. It was imagined by Gendrin and Donné that the blood itself was the source of the pus, and that it was developed by the metamorphosis of blood globules into pus cells; and they imagined that the change of form to a sphere, which the blood discs undergo, when submitted to the action of certain fluids, was an indication of the change. This doctrine has, however, been long since exploded.

A more reasonable explanation, and one founded upon analogy, is that the pus is secreted by the inner surface of the vein, by a metamorphosis of epithelium. Vogel has long since demonstrated, on the mucous membranes, that pus is producible by a change of epithelial cells, and this suggests an explanation, — why, in an unbroken vessel, pus may be produced in great abundance. Wherever epithelium exists, it appears that pus cells may be generated without lesion of surface; especially where the action is started by contact of pus from some other source. This certainly happens in serous cavities,—pleura, pericardium, &c.; and we may, from analogy, judge that the same occurs in veins. This doctrine is entertained by the high authority of Hasse: he observes, — "In accordance with these views, the puriform masses, generated within the veins, would be developed as follows: — First of all the cells of epithelium-lining discovered by Henlé, separate from the internal membrane of the vein, so as to give the inner surface of the vessel the dull appearance already described, and to render it more susceptible of a morbid tinge from imbibition. The next change affects the passing blood corpuscles, which assume a spheroid or else a gibbous appearance, advance with a slow revolving movement, or cling to one another, parting with their serum and with their pigment. The internal membrane of the vessel generates new imperfect epithelium cells, which mingle with the altered blood, and finally actual pus-globules, which, when congregated in sufficient number, completely arrest the current of the blood, and affect the blood-corpuscles in the manner already pointed out. The simultaneous effusion of both fibrin and albumen now serves to complete the formation of a plug, which differs in external characters according to its more or less rapid development, and to the varying proportions of its constituent parts. The plug, thus originating, afterwards undergoes further changes." *

The actual changes that occur, and are obvious to the naked eye, affect the plastic plug, the fluid contents, and the parietes of the vein. In suppurative as well as adhesive phlebitis, plugs of lymph and coagula are formed, and are partly the result of inflammatory action, and partly they are the direct result of the contact of fluid pus with the blood.†

The plugs that form in suppurative phlebitis are softer, more numerous, and vary in form. They soon become broken down, and exhibit disintegrated fibrin mixed with genuine pus. The coagula become softened, first in the centre; they loose their laminated structure, and ultimately break up. These coagula, in phlebitis the result of infected blood, must not be considered as any indication of the locality in which the disease has originated. In such cases the whole circulating mass is infected: little portions of coagulating fibrin, entangling pus-cells, are continually passing through the vessels, and here and there attaching themselves to the lining of the vessel, light up circumscribed regions of inflammation. This coagulation is a remedial effort: by its means the materies morbi is shut up and circumscribed by a harmless coagulum: circulation in the affected vessel is suspended and the poison cannot again mix with the blood. Perhaps these coagula sometimes become absorbed, or organised and obliterate the vessel; at other times they suppurate, and the walls of the vessel become implicated and ultimately give way. "The formation of matter being brought about within the inflamed vein, its membranes have likewise to undergo a further change. Their colour now inclines to a greyish white; they become softened and thickened, are no longer to be distinguished from one another, and form, in conjunction with the surrounding textures, a nearly uniform membranous layer of

* Hasse's Pathological Anatomy, p. 16.

† The influence of pus in causing coagulation of the blood may be seen in the following experiment: —"An abscess was opened in the groin, and a quantity of pus received into a gallipot; some blood from the divided vessels was also received into the same vessel; they were then stirred together, and in *two minutes* the mass coagulated. Some blood taken from the same patient in the same manner, but not mixed with pus, coagulated in *eleven and a half minutes.*"—*Lee on Phlebitis*, &c. p. 27.

a lardaceous aspect and character. By and by a turbid puriform fluid is often found deposited at intervals in the cellular texture; in some instances where the suppuration is vigorous in the vicinity of the vein, the latter traverses the purulent channel for a considerable space, denuded of its entire circumference. Here the membranes of the vein gradually soften, and at length melt down, so to speak, until no further vestige of their texture is discernible within the common centre of suppuration." * If, however, this circumscription of the pus by means of coagulum does not occur, and it floats through the vascular system, it produces a variety of secondary effects remarkable and important in their results.

The products of this secondary action are known as "*purulent deposits*," or "lobular abscesses." Strictly speaking, they are not *deposits* of pus; but the pus is "translated" from one part to another, and there becomes the originator and centre of a fresh abscess.

The actual mode of production of these lobular abscesses has been the subject of much discussion; but the evidence upon the various points appears to resolve itself into the following explanation. The pus-cells being bodily introduced into a vein, or generated in it, pass forward in the circulation till arrested in the capillaries by their size being too great to admit of their passage: they then excite inflammation of the parenchyma of the affected organ, which leads to condensation, and, subsequently, to suppuration: the pus-cells being the excitants of the inflammation, which is suppurative, not only from its intensity, but from the fact that pus germs are furnished by the same body as originates the inflammation, and thus more pus is generated.

The appearances of these local abscesses, which are, strictly speaking, foreign to our present subject, are determined by the character of the organ in which they occur.

There appears to be some general laws as it respects the development of these abscesses. They occur in those organs which are most vascular, and through which the largest quantity of blood passes in the smallest space of time; thus the lungs and liver are affected the most abundantly. Again, after the blood has been infected and the pus added to it, that system of capillaries is first affected, through which the fluid first passes; the capillaries, as it were, filtering off the pus-cells and retaining them. Thus, if pus gets into the systemic veins, the capillaries of the lungs will be the first to arrest their progress; and when this happens, as is generally the case, lobular abscesses are most abundantly, or exclusively, found in those organs, and when found elsewhere also are most advanced in the lungs: when, however, the portal system is the vehicle of the pus, as occasionally happens after operations on the rectum, for example, we find the abscesses in the liver. These laws are quite correct in the main; but there are some exceptions to them, and these exceptions are quite explicable; for though pus-cells are for the most part too large to pass capillaries, especially with their tendency to coagulate blood, they may nevertheless pass through some of the larger ones; and it must be admitted that disintegrated pus globules may pass through the smallest vessels: hence, in some instances, the laws here suggested are not exemplified.

* Hasse, loc. cit. p. 18.

The results of phlebitis are either *suppuration*, *resolution*, or *obstruction*, the consequence of organisation of the effused lymph. Upon the latter subject some observations are necessary.

Obliteration of Veins.—Obliteration of veins, the result of phlebitis, may be either incomplete or complete. Hasse mentions two forms of partial obliteration of veins; the first of which has also been described by Carswell. This form consists of a thickened and turgid condition of the vessel's walls, as if they had been macerated; at the same time they are closely connected with the surrounding areolar tissue. Within the vein, and intimately connected with the lining membrane, is a hollow cylinder of fibrin, firm and whitish on its exterior, and soft and dark-coloured within; the interior being bathed with the circulating blood. Dr. Carswell's explanation of this, in which Hasse coincides, is that the soft centre of the plug is carried away before the circulating current, whilst the exterior becomes organised and united with the interior of the vein.

In the other form he describes the vein as reduced to a whitish cord, and filled with an organised plug. "Betwixt this plug and the thickened coats of the vessel, round about the periphery of the former, were several little canals, which, running along the whole extent of the vein, had already begun to re-establish the circulation. In all probability the impulse of the blood below had, during the first period of inflammation, here and there severed the plastic plug from the parietes of the vessel; subsequently, the above plug being organised, and the intervening blood absorbed, several peripheral channels would form, instead of a single central one." *

In complete obliteration the vein diminishes in size, shrinks nearly to a cord, and becomes pale and soft. The plug also becomes reduced in size and organised, and adheres firmly to the lining of the vein. How the plug receives its vessels and communicates with the vasa vasorum of the vein, I am not prepared to state. But fibrin thus isolated probably has the inherent power of generating vessels, which ultimately communicate with those of neighbouring textures. The secondary consequences of obliteration of veins, — œdema, Phlegmasia dolens, &c. cannot here be considered.

Healing of Wounds in Veins. — The condition of the wound and its mode of healing depend upon the character and direction of the

* Hasse, loc. cit. p. 26. I beg to make abundant acknowledgments to the very valuable writings of this author, from whom I have drawn largely.

wound. If the wound be linear, and made in the axis of the vessel or somewhat obliquely, and there be not much bleeding, its lips will come together, adhere, and rapidly form a linear cicatrix. If, however, it be transverse, or if much bleeding occur from it, a coagulum will form in and over the aperture. "An oval naked coagulum forms the plug of the orifice, and a flattened covered clot, which is an extravasation into the cellular sheath, extends to some distance around it." * In twenty-four hours the lips of the wound are found separated, the edges are everted and adhere to the clot. At the expiration of three days the internal margin of the wound is elevated and rounded, and a thin, narrow, membranous expansion, partially extending over the inner surface of the clot, is seen to be continuous with the everted edge of the internal tunic. The clot is more compact and lamellated. At the fifth day the membranous appearance extends over the whole inner surface of the clot. Subsequently the clot becomes more and more absorbed, and the new membrane, extending from the lips of the wound, becomes more organised. Vasa vasorum can be seen on it by means of a lens from the twelfth to the sixteenth day. "On the twentieth day it is only possible to distinguish the recent from former wounds, by the tenuity, smoothness, and transparency of the new membrane compared with the old, which is dense, tough, and wrinkled." These dates, &c. refer to the wounds made in ordinary bleeding operations; in larger wounds the process is proportionately longer. The wound is ever after indicated by the peculiar thin, transparent, extensile membrane with which it was repaired. If a vein, having one of these cicatrices in it, be injected with water, the new membrane bulges out, on account of its elasticity, into a pouch or bag.† Mr. Travers is quite convinced that this new membrane is continuous with the internal membrane of the vein.

Effects of Ligatures on Veins. — The effects of ligatures on veins are different from those on arteries. The coats of the vein are, by the ligature, thrown into longitudinal folds, which are indicated when the vessel is slit up, and its interior examined. The effect on the elementary coats of the veins is different from that produced by ligature on the arteries: instead of the deep cut through the inner and middle coat, which occurs in the latter, there is but a slight indentation, corresponding to the ligature on the vein. This is produced by the lesion of the thin internal tunic, and that alone. As regards the rest of the thickness of the vein's walls, it appears that the outer or cellular tunic is divided, leaving the middle condensed portion of the venous wall uninjured. Upon a close examination, however, it is found that one element — namely, the yellow elastic tissue — is divided throughout the entire thickness of the outer and middle coats, leaving the continuity of tube to be maintained by the white fibrous element, which does not suffer division; and therefore that part of the wall where the white fibrous element is most condensed and abundant is that where least impression is made by the ligature. A thin, tightly tied, string produces the deepest impression.

According to Mr Travers, when a ligature has been applied for a period of from twenty-four hours to five days, it has produced the following changes: — "The vein above and below is thrown into longitudinal folds on either side of the ligature. The portion next the heart is perfectly empty and collapsed; that next the extremity is filled to distension by a long, and, generally, firm, coagulum of blood, which is a mould of the vessel, and bears the impression of its semilunar valves. The coagulum extends for several inches; it is not always compact and lamellated, and adhering to the internal tunic, being sometimes less consistent and broken; but it always fills the calibre of the vein. There is no blush upon the internal tunic, much less any sign of adhesive inflammation, or thickening of the proper coats of the vein, or agglutination of its contiguous folds; these folds being effaced on the removal of the ligature; but the cellular sheath is thickened by a deposit of lymph in the vicinity of the ligature." * If two ligatures be applied, and the vessel divided between them, the ends retract about an inch. At the seventh day the interstitial deposit of lymph among the areolar tissue around the vein is very dense, and forms a hard fibrinous mass, through which the ligature runs in a sort of canal. According to Mr. Travers, ulceration commences on the ninth day, and lasts from fifteen to twenty-five days. "The ulcerated ends of the vein formed a crescentic sweep, and were separated to the extent of an inch, and fastened by adhesion to the cellular sheath, which was much extended and thickened by a subjacent deposition of lymph, so as to form a smooth solid bed between the divided ends of the vein. The internal membrane of the superior portion of the vein had a thin ragged edge, where it had been severed by ulceration. The lower edge was smooth and blended in with the bed of the wound. The extremities had undergone no contraction but that produced by the adhesion of the severed extremity to the sheath. The portion of the vein next the heart was empty. The upper† was filled by a dark lamellated coagulum of blood, adhering very strictly to the internal tunic, which was discoloured by it. On carefully separating the outer lamellæ which coated the interior of the vein, I could not discover any thickening of the proper coats of the vein, nor any appearance of inflammatory action within its canal, nor was any such appearance indicated in the lower portion of the vein.‡

* Travers, loc. cit. p. 246.

† See the beautiful plates accompanying Mr. Travers's essays before referred to.

* Travers, loc. cit. p. 252.

† The jugular vein is referred to.

‡ Travers, loc. cit. p. 253.

Phlebectesis — Varix. — Dilatation of veins is not only the commonest morbid change in veins, but is the most frequent single pathological condition that occurs in the human body.

Varix is a condition of vein which occurs in every possible variety of degree, and in various localities, and is generally developed by the superaddition of some mechanical exciting cause upon a constitutional predisposition, — by the operation of some local physical influence upon veins, which, in common with the other veins of the body, already possessed an abnormal laxity or softness of texture that favours their dilatation.

The structure of veins, already described, pre-eminently favours their dilatation : — a structure consisting almost solely of longitudinal fibres, with comparatively few in a circular direction to brace up its calibre, presents little to restrain its dilatation beyond the lateral adhesion of the contiguous fibrous rods and their matting together by a certain amount of lateral branching. The coats of veins moreover are very thin, and the amount of distending force applied to them often very considerable.

The anatomical relations of certain veins give them, when in a state of varix, considerable peculiarities, and various distinctive appellations have been conferred upon such local affections, — *varicocele*, *hæmorrhoids*, &c.: their pathological identity is, however, indisputable.

Though varicosity of the veins is, for the most part, confined, in one individual, principally to one locality, it nevertheless appears to depend upon a vice pervading the entire venous system, the effects of which are more particularly called out in one locality by the existence of some mechanical excitant there present. I cannot at all agree with Hasse and Landouzy, " that the full development of this disposition in one locality *prevents* its outbreak in another." This doctrine has, however, been supported by a show of argument. Thus it may be truly said that hæmorrhoids, varicocele, and varicose subcutaneous veins very seldom exist together in the same individual : the concurrence of either two of them is unusual, and much less frequent than their solitary development ; and moreover the different forms are met with, as a rule, in different classes of society : — thus hæmorrhoids are most frequent in the affluent, varicocele in the sensual, and varix of the lower extremities in the labouring classes. Again, the different forms appear at different periods of life, — varicocele about or soon after puberty; hæmorrhoids and other varix usually about manhood. But all these arguments fail, when it is recollected that in each of these suggested instances there is some special circumstance, which, acting as an excitant, superadded to a previous constitutional disposition, might account for the particular locality in which the disease makes its appearance, and the particular time at which it occurs. If in all these instances obstruction to the circulation cannot be made out, there is some cause of greater vascular activity, which is also seen to be efficient in the production of phlebectesis. Hæmorrhoids are most frequent in the affluent, because their mode of life leads to greater vascular activity in the alimentary canal, and to frequent portal obstruction : varicocele in the sensual, from the greater stress of blood upon the spermatic veins ; at puberty also, from the same cause : the labouring classes likewise are afflicted with saphenous varix on grounds similarly explicable. It is because there is particular emphasis laid on one particular organ in each of these cases that the specific form of phlebectesis is assumed in the separate examples. And where such influences have been compound, other effects have followed, combining more or fewer forms of varix. It cannot therefore be said that one form of phlebectesis *prevents* another, or even diminishes the chance of its formation ; the truth is, that the same individual is not liable to be exposed to the exciting cause of more than one form, — that the predisposing condition of the veins may be universal, but in one set alone is the morbid change called forth.*

Phlebectesis may conveniently be divided into several forms. Andral has made the following division : —

" First species. Simple dilatation, unattended by any other alteration, either affecting the whole length of the vein, or existing only at intervals.

" Second species. Dilatation of the veins, either uniform or at intervals, with thinning of the parietes at the dilated points.

" Third species. Uniform dilatation of the veins with increased thickness of the parietes.

" Fourth species. Dilatation of the veins at intervals with thickening of the parietes at the points where the dilatations exist.

" In these two latter species, the vessel increases in length as well as in breadth, and in consequence becomes quite tortuous in its course.

" Fifth species. Dilatation of the veins, with the development of septa or partitions, which divide the interior of the vessel into small compartments, that allow the blood to stagnate or to coagulate, &c.

" Sixth species. Dilatation of the vein, its interior being divided into a number of separate compartments, as in the preceding species, and in addition its parietes drilled by a number of minute holes, which allow the blood to pass from the vein into the surrounding cellular tissue," &c.

These include all the forms of phlebectesis as far as systematic division is concerned.

* This may be very pointedly illustrated by instancing the two spermatic veins in varicocele respectively. It cannot be said that varix of the left prevents varix of the right spermatic vein ; for both, not unfrequently, occur together. It cannot be said that there is any difference in structure or constitution between the two veins in the same individual. Then, why should the left, and the left alone, be, in nine out of ten cases, affected ? Simply because a strong mechanical influence operates on one and not on the other vein.

The first species simply includes a general predominance of the venous system, — a disproportionate size of the veins. It is of very frequent occurrence, and is indicated by a plethora or distinctness of the veins of the subcutaneous system. This is often seen in the veins of the back of the hand. It is not to be considered strictly morbid, — it is in many individuals an original conformation, and in others merely temporary, the result of warmth, strong exercise, pressure on a venous trunk, &c. It is common, nay general, in old people, though the healthiest. It may be here observed that the capacity of veins, as well as that of arteries, increases with age.

The second species represents a condition unquestionably morbid. It consists in a dilatation of the vein at the expense of its walls, they becoming attenuated in proportion to the increase of the vessel's calibre. This appears to consist essentially in a separating of the longitudinal fibres of the outer coat, by which the internal membrane is permitted to dilate or protrude. The dilatation is seldom cylindrical, it is usually unequal and in pouches. These pouches are usually more or less globular or oval; sometimes, however, they are constricted, or form pear-shaped, or even pedunculated, tumours.

The third and fourth species of Andral's division are modifications of the same condition, and seem to be in many cases the direct but gradual result of the first. Whether the dilatation be general and equable, or partial and irregular, the thickening is confined to the dilated portion, and is doubtless a reparative condition, — an effort to resist by increased strength of the vessel's walls any further stretching; and it may be observed that in this thickened form of phlebectesis, those large, pouchy, and tumour-like, dilatations do not occur. In these forms the dilatation is more regular and cylindrical, or increasing somewhat evenly in passing from one part of the vein to another. In almost all these cases there is increased length, sometimes very considerable, so as to make the vein assume a serpentine or tortuous course; in some instances the vein remains perfectly straight. The increased thickness arises from the superaddition of fibrous tissue in the external coat, probably developed from a sub-inflammatory plastic exudation among the normal tissue of the outer coat, itself an effect of the stretching, in the dilatation of the vein. The amount of thickening varies in different cases: in those fully formed it is often very considerable. The increased thickness of the vessel's walls prevents it from collapsing when cut through: it remains patent like an artery. The colour of its tissue differs, however, from the arterial; it is reddish white, and pale, like the normal venous tissue. Besides thickening of the coats of the veins, they become indefinite and very hard; the outer coat becomes completely blended with the areolar tissue of the sheath of the vessels; by this means the walls, which are often thicker than those of an artery of the same size, are with difficulty pressed together.

As regards the fifth species, I agree with Hasse, that it more deserves to be considered as a mere variety of the others than as itself distinct. The septa are probably not new formations.

The sixth species, whilst it evidently refers to a particular form of venous dilatation, is obviously misdescribed; the minute holes "drilled in the sides of the veins" in this species being in reality nothing more than the mouths of small and dilated veins, whose dilated and attenuated walls are not easily recognised, and thus the blood is thought to escape into the cellular tissue.

To these may be added certain varieties of erectile tumour, which consists essentially of modified capillaries, but on which the venous character is conspicuously impressed. In these cases there are oval or spheroidal tumours of a bluish or purple colour. They are composed of dilated capillary veins, which are supplied by enlarged arteries. The veins are stretched into saccules and crypts, and the blood is removed from them in veins disproportioned to the size of the affected part, and often themselves varicose.

Having considered phlebectesis in general, I may conveniently devote some remarks to a few of the special forms of varix.

Varices of the Leg. — Varices of the lower extremity usually occur after the commencement of adult life. They are generally the result of habitual toil in the erect posture; they result also from obstruction to the circulation; and a not unfrequent source of obstruction has of late been displayed in the fascia lata that forms the saphenous opening. Briquet has shown that this affection is more common amongst males than females. In 258 males examined by him 71 had varix of the leg; in 485 females, 42 were affected.

There is another distinction in the disease as it appears in the two sexes; in man one trunk is usually affected, or, at all events, the disease is confined to vessels of larger size; whereas in the female, the smaller cutaneous twigs are generally the subject of the disease, and then present an elaborate series of purple ramifications, very superficial and distinct; and often associated with the latter are circumscribed local varices of greater size. This is the general rule, but it is liable to exceptions; each form may occur in either sex, but the latter is almost always confined to the female. This circumstance was, I believe, first pointed out by Hasse.

It is unusual for all the veins of the leg to become varicose; it is usually confined to one branch of the internal saphena: the external saphena may however likewise be affected, or several branches of each. It is uncommon for them to be affected symmetrically; the right leg, according to Briquet, is most generally the subject of varix.

Varices of the leg are arranged in various forms: in some cases they consist of packets of folded and reduplicated tubes, which, not a little, resemble, when seen through the skin, the vesiculæ seminales; in other examples the varix is single, straight and prolonged. A remarkable instance of this occurred under the observation of the author not long since; it consisted in a varicose condition of the internal saphena on one side alone: the vessel formed one large, straight, uniform cylinder from the saphenous opening to the inside of the foot, measuring about two thirds of an inch in diameter.

Phlebitis often occurs in varix of the leg. The valves moreover are subject to peculiar malposition, dependent upon the distension of the vessel's tube: these conditions are noticed elsewhere.

Varicocele, or varicose dilatation of the spermatic veins is another peculiar form of phlebectesis. In its general anatomy it differs in no respect from the other forms of varix.

Varicocele appears to be dependent upon sexual development, and occurs principally about puberty. Landouzy has demonstrated this as follows: —

In 41 cases	13 occurred between	9 & 15 yrs. of age.	
	20 „	15 & 25	„
	3 „	25 & 35	„

The influence of mechanical pressure in causing this malady is very strikingly shown by the fact that the disease is almost confined to the left side, on account of the long and uninterrupted current of blood which bears upon the left vein, by means of the high juncture of the spermatic vein of that side with the renal vein. Breschet found in 120 cases but one on the right side.

Hæmorrhoids, in their relation to phlebectesis, consist merely of dilated veins, situated in the vicinity of the anus, and in which chronic inflammation and thickening of the external coat and surrounding areolar tissue is very conspicuous. The dense covering of areolar tissue, and the comparative smallness of the enclosed vessel's calibre, have given rise to different explanations of the pathological origin of piles.

Le Dran, Racamier, Delaroque, Cullen, Chaussier, and others have considered them as encysted coagula of extravasated blood. Delpech and Cruveilhier describe them as tumours of erectile tissue. But by far the most numerous and reputed pathologists, among whom may be mentioned Andral, Stahl, Petit, Morgagni, Hodgson, Lobstein, Froriep, and Brodie, concur in the now generally received doctrine of the origin of hæmorrhoids in varicose veins.

Hæmorrhoids consist of oval, ovoid, or round masses with broad bases, situated either just within, or just without, the sphincter ani. On examining the texture of these tumours, they are found to consist of cells or cavities of various sizes, surrounded by layers of red, dense, areolar tissue. These, which vary in shape, are lined internally by the smooth lining membrane of the vein, and are perforated here and there with the apertures of small communicating and tributary veins. The absolute continuity of these cells with the venous cavity has been proved by Hasse and Brodie, who have injected them from the arteries; the former has also injected them by the veins.

They are very apt to inflame and become lined with lymph, or stuffed with coagula.

Varices occur in all situations and in every variety: instances are on record where they have occurred in the veins of the œsophagus, lips, eyelids, bladder, heart, &c.: indeed there appears to be no region which is free from the occasional development of this disease.

Rupture or Perforation of Veins. — A number of pathological examples, in which perforation of the vessel's walls is the conspicuous character, may be conveniently, though, it must be confessed, not very naturally, classed under this head. Either with or without previous change, and that change very various, the lesion may occur, so that the only condition common to these instances of morbid change is *a breach in the venous cylinder*.

A rupture, without previous morbid change in the vessel, and which may occur in any case where the tissues of the vein are thin and weak, may be produced by an unusual amount of internal tension of the contained fluid. So again, an attenuated or ulcerated state of vein may yield before an amount of distension that is neither excessive nor unusual: rupture is the result in either case.

Destructive disease may, as well in veins as elsewhere, attack the tissues of the organs in question, — suppurative inflammation, ulceration both extrinsic and intrinsic, extension of malignant disease, &c.: perforation is here the issue.

In the rupture of a previously healthy vein the change consists in a rent or tear of the structure, the surrounding tissues being normal: the rent is sharp, and more or less regular. In perforation from ulceration, &c. the aperture is rough, irregular, and jagged; the parietes of the vessel are thinned down towards the hole, are much thickened more remotely, and the orifice is ragged and shreddy.

Sudden or extreme obstruction to the circulation, thus causing excessive distension, has produced rupture of the healthy veins. Bichat mentions instances of rupture of the veins of the lower extremities during pregnancy; Lee, those of the labia during labour. Violent muscular exertion has ruptured veins, by producing local congestions: Hodgson, for example, has witnessed rupture of the veins of the leg during cramp of the gastrocnemius; I have three times seen rupture of a vein on the dorsum of the foot during strong exertion. Andral narrates an example where, during a violent struggle, the vena cava inferior was ruptured; "the borders of the perforation seemed as if they had been torn asunder, and the coats of the vein in the neighbourhood were perfectly healthy." The peculiar bloodlessness of the surface, and consequent deep-seated congestion which occurs during rigors or the sudden application of cold to the surface, has ruptured the large internal veins. Portal tells us of a case of rupture of the vena cava superior from a patient getting into a cold bath: and Senac mentions the rupture of the large internal veins as occurring in the rigors of intermittents.

Rupture of the inferior cava from disease, has been described by Dr. Squibb, in the *Philadelphia Medical Examiner* for 1847. "The vein at this point had been very much dilated, and its coats much diseased and thinned: a semiorganized mass or clot, which was contained in the dilatation, was connected by its surface to the softened coats of the expanded vessel, and the rupture had occurred at the junction of the edge of this mass with the side of the vessel, and not at the projecting point of the dilatation. The tumour was on the anterior portion of the circumference of the vessel, and was overlapped by the edge of the liver, and by a portion of the stomach."

Morgagni mentions the rupture of a varicose azygos vein, the result of extreme varicosity. Perforation of veins from suppurative inflammation or ulceration is not uncommon. The cavities of the veins, especially in the stomach and uterus, are often laid open by the extension of malignant disease. But the commonest form of venous perforation is from the tegumentary varicose ulcers of the leg, which is originally extrinsic to the vein.

The following enumeration of ruptured or perforated veins is from Andral. "It has been seen, first, in the superior cava, both within and without the pericardium; second, in the inferior cava; third, in the vena portæ, both within and without the liver; fourth, in the splenic vein; fifth, in the jugular vein; sixth, in the subclavian vein; seventh, in the veins of the extremities; eighth, in the veins that run between the coats of the intestines."

Affections of the Valves of Veins are partly mechanical and partly dynamical. The most frequent change they suffer from is the result of the distension of the vein in which they are placed; but they are occasionally the subject of the same changes as occur in the vessel itself. In varix the valves are not necessarily damaged, though from the increased size of the vessel in which they are placed they are disproportioned to their office, and become useless. Instances are mentioned by Stanley, Langstaff, and Dr. R. Lee, where the valves in varix were quite healthy, thin, and transparent, but drawn aside and inadequate to cross the vessel's tube. The usual result of varix is to injure the valves: they then become torn in shreds or perforated; or the attached margin becomes detached, and the valve is reduced to a membranous thread, which stretches across the diameter of the vessel. In other instances the valves are rendered opaque and thick,—the result of chronic inflammation. Whenever any affection of the valves occurs, they are apt to become coated with lymph; and when a vein is the seat of plastic inflammation, the valves usually become ragged fringes of lymph.

Phlebolites. — The curious bodies called *phlebolites*, *phlebolithes*, or *vein-stones*, which have excited much interest in the pathology of veins, are true vascular calculi, — are calculi or earthy concretions deposited from the blood in the veins; and though their mode of formation differs considerably from those other bodies which form in other hollow organs, and which we call calculi, they are still quite as much entitled etymologically to the same designation.

At a very early date, among the writings of Realdus, Columbus, and Bartholin, phlebolites were recognised and described; but it was not until Otto, Tiedemann, Cruveilhier, and Carswell devoted their attention to them that they excited much interest. Matured phlebolites are, for the most part, oval or roundish bodies, sometimes irregular and flattened; they are sometimes prolonged and much attenuated at one extremity, corresponding to the distal end of the vein in which they are embedded. They vary much in size, from a grain of millet seed to a pea, or even to a hazel nut; their form also differs. Dr. Lee describes a cylindrical vein stone, which was found in the right common iliac vein of the late Lord Liverpool; it was an inch or more in length.

These concretions are of a yellowish or white colour; they are of varying density, being sometimes of bony hardness, and at others much softer, with a firmer nucleus, which is always harder than the other parts of the stone. When sections are made the cut surface presents a series of concentric rings, — there being at different distances from the centre sufficient change of colour and density to mark each annulus; so that the calculus is thus seen to be composed of successive concentric laminæ, hardest in the centre, and gradually becoming softer in proceeding outwards. They are frequently seen surrounded externally by a layer of plastic material, looking like a membranous investment; at other times they are firmly imbedded in a dense coagulum; but in the majority of instances they are free from any covering. The hardest stones, however, contain, intermixed with the calcareous matter, much soft animal material; for, when desiccated, they diminish in size; and, unless the layers have received equal proportions of earthy deposit, they become irregular.

Phlebolites have been made the subject of chemical analysis. According to Gmelin, the following is their composition: —

Animal matter - -	27·5
Phosphate of lime - -	53·5
Carbonate of lime - -	15·5
Magnesia and loss - -	3·5
	100·

This analysis has been repeated with the same general results by Prout, Kemp, Hasse, and Lehmann. They have since been submitted to another analysis by Schlossberger, who has given his results more in detail, as follows: —

Phosphate of lime	50·1
Phosphate of magnesia	13·7
Carbonate of lime	8·3
Organic matter	20·4
Water	6·1
Loss	1·4
	100·

These, then, are phlebolites completely matured. In those less completely developed the phlebolite consists of an altered coagulum, in the centre of which is earthy matter, surrounded by white fibrinous concentric layers. Cloquet has described one, which was not fully formed, in which the calcification was incomplete. It was taken from the inferior cava, and consisted of a fibrinous mass, containing a calcareous centre, from which a number of rays of the same substance passed through the fibrinous matter toward the circumference. Cloquet describes one of similar structure, which he saw in Sœmmering's museum, and which was also taken from the inferior cava. In a still more primitive condition these calculi are recognisable. "On drying the coagula found within dilated veins, previously to their having coalesced with the internal membrane, they shrink together, grate under the knife, and exhibit calcareous induration at certain points, even in cases where it had not been at all suspected."*

As regards the origin and development of phlebolites, only one opinion is now entertained, namely, that they are developed from modified coagula. Andral, however, gives the following explanation. After speaking of calcareous degeneration of the coats of veins, he goes on to say, "these calcareous concretions, instead of lying between the coats of the veins, sometimes push the internal membrane before them, and project into the interior of the vessel; the membrane in such cases generally contracts behind the concretion, and forms a peduncle, which serves to attach it to the side of the vein. It is probable that these peduncles are sometimes ruptured or absorbed, and thus the concretion is completely detached from its connection, and drops loose into the vessel. This rationale may serve to explain the origin of some of those calcareous concretions which have been found in the centre of the venous coagula.†

Hodgson imagined that phlebolites were formed in the neighbouring textures, and found their way into the veins by progressive absorption.

Dr. Carswell has described and illustrated the true method of their formation in detail, exhibiting their successive changes in the progress of maturation. At first a coagulum of blood is formed, which becomes condensed and laminated in the centre; the colouring matter of the blood subsequently becomes absorbed, and leaves ordinary yellow fibrin; this also becomes lamellated throughout. After this calcification commences in the centre and proceeds outwards till the whole is calcareous.

This mode of formation is maintained also by Otto, Tiedemann, Lobstein, Cruveilhier. Errhman, Briquet, and Hasse.

The position of the phlebolite within the vein, and the condition of the vein and phlebolite respectively, are subject to much variety.

In the dilated pouches, which sometimes form in the sides of the veins, coagula are frequently produced, which may terminate in phlebolites. The pouch being filled, the walls become atrophied, the inner surface becomes rough and cellular, and closes firmly round the calculus, sometimes making it appear external to the vein. At other times, not only the pouch, but the entire calibre of the vein, becomes implicated and stuffed with calcifying coagulum; in this case a portion of the tube becomes obliterated. In other instances the phlebolite is free in the cavity of the vein, is loose and movable, and the vessel that contains it is still permeable to the circulating current. Such phlebolites, though loose and movable, are frequently surrounded by coagula of blood; sometimes by a layer of fibrin. They have occasionally been surrounded by a thin layer of fibrin, and attached at one point to the side of the vein by a sort of peduncle, the rest of the body hanging free into the cavity of the vessel. Tiedemann very naturally suggests that in these cases the peduncle is produced by the effusion of coagulable lymph, the result of inflammation, caused by the presence of a foreign body.

Phlebolites have been discovered in very many of the veins: they have been found in the vena cava inferior, the renal, the dorsal, the common iliac, anterior and posterior tibial, the saphena and other superficial veins of the lower extremities, the hypogastric veins; also in the uterine, the vaginal, spermatic, vesical, prostatic, and hæmorrhoidal, veins. They have likewise been seen in the splenic and mesenteric veins. Their most frequent and most abundant position is in the veins of the pelvic viscera. In number they vary considerably: there are generally, though not always, more than one. Tiedemann found thirty-six in the spermatic veins of one individual,—fifteen in one, and twenty-one in the other.

They occur almost always after middle age. They produce no injury or inconvenience; nor is their presence known, except in a few situations, during the life of the individual.

There are some general circumstances relative to phlebolites which are striking and curious. They always occur in veins below the diaphragm, — in depending veins, — in veins which circulate their blood against the force of gravity.

According to Hasse, they always occur in conjunction with phlebectesis.

They frequently, perhaps generally, occur in veins returning the blood from diseased organs, — from a diseased testicle or prostate, from an ulcerated rectum, from an inflamed or

* Hasse's Pathological Anatomy.

† Andral, Précis. d'Anatom. Pathol. tom. ii.

cancerous uterus, from an ulcerated leg, &c. Examples of all these are on record.

What, then, determines their development? This question it is not easy to answer; all we can say is, that those circumstances which facilitate mechanically the coagulation of the blood, favour their production; and it is not improbable also that a vitiated state of blood may predispose to and favour their development: it is certainly probable that the predisposing causes, whatever they are, may be started into activity and be made efficient for the production of these bodies, by some temporary local disturbance of the circulation, or by some slight subinflammatory condition, which varicose veins readily take on, and which, were it not for the existence of predisposing circumstances, would soon be resolved.

Calcareous Degeneration of Veins. — The transformation of the walls of veins into earthy tubes, or calcareous deposition among their tissues, is infinitely less common than in arteries. It still however does occur, and apparently in the same manner, by the same progressive changes, and from the existence of the same constitutional tendency, only in circumstances of greater intensity.

Occasionally patches of atheromatous deposit — consisting, as in arteries, of cholesterine, oil, and phosphate of lime, — are seen on the inner surface of veins, though they are always much smaller, and less general than those which are found in the arteries of the same individual. They present a white opaque appearance, and produce a slight elevation of the surface where they are situate. This deposit becomes converted by degrees into bony matter, as in arteries; but instances where this has existed to any considerable extent, are very rare.

There are, however, some few on record. Bailie has described ossification of the inferior cava. Morgagni refers to a case observed by Bonazolius and Stancarius, in which the cava and emulgents were much dilated, and converted partly into cartilage and partly into bone. Beclard mentions an instance where the femoral vein was calcified, and it was lying in contact with a still more ossified femoral artery. Horn noticed ossification of the femoral and uterine veins. Mr. Hodgson relates an instance of ossification of the saphena, in which one calcareous patch measured an inch in length; and Phœbus states that he saw in an anatomical museum an ossified saphenous vein taken from a patient fifty-six years of age, who died of cancer of the stomach. By the calcareous deposit the vein was rendered thick and inflexible; but at the points corresponding with the joints of the leg the vein could be bent. The deposition was between the coats of the vein, and was less regular than that which is found in the coats of arteries. The lining membrane was thick, opaque, and nowhere broken. Microscopically, the deposit presented irregular projections and excavations. Furst and Bonetus have found the coronary veins of the heart converted into bone. Otto enumerates instances of this change as also having occurred in the splenic, portal, brachial, femoral, and coronary veins.

A concretion of phosphate of lime, the size of a nut, was found by Andral in the parietes of the external saphena. This might have been an attached phlebolite.

Fatty Tumours. — Fatty tumours are occasionally developed in the walls of veins around the areolar tissue. Andral mentions one, — "I once saw a case of this description, in which a tumour, presenting all the anatomical characters of adipose tissue, was developed between the coats of the vena portæ, near its entrance into the liver. This tumour, which was about the size of a walnut, projected into the interior of the vein, and almost entirely obliterated its cavity.*

Entozoa in Veins. — There is upon record a unique example of acephalocysts being developed in the pulmonary veins of the human subject, in which pouches were formed for their reception. The observation was made by Andral. I quote his description *in extenso* from the "Clinique Médicale."

"Several of these (acephalocysts) were lodged in pouches with a smooth surface, which at first seemed to be so many cysts. Others of them empty, and rolled several times on themselves, were contained in narrow canals, the elongated form of which they assumed. The inner surface of these canals was smooth, like that of the great pouches; they ramified like vessels. We soon ascertained that at each pouch a vessel terminated of small calibre, which, to form it, underwent greater or less dilatation. We then dissected the pulmonary veins, at their entrance into the heart, and we traced them into the lungs: when we had come to their almost capillary divisions, we began to perceive several of them present a considerable number of enlargements, which were filled with hydatids. After being thus dilated, the vein resumed its original calibre; then, a little further on, it was again dilated. The largest of the pouches might have contained a large nut, and the smallest would admit a pea. They existed equally in both lungs. The hydatids, which they contained, had all the characters of acephalocysts; several presented small points of a dull white colour in their substance; others presented on their inner surface a great number of miliary granulations. Most of them were burst."†

Another entozoon, the *Distoma hepaticum*, has been found in the (hepatic) veins. Several examples have been recorded, but have again been questioned. The matter has, however, now been set at rest. In 1830, M. Duval, at Rennes, demonstrated to an anatomical class several of these parasites in the hepatic veins of a man. They were floating about in the fluid blood. The vessels themselves were free from any lesion.‡

* Andral. *loc. cit.*
† Andral, Clinique Médicale, p. 555.
‡ Duval, Gazette Médicale à Paris, 1842.

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(*S. James H. Salter.*)

VENOUS SYSTEM (in descriptive human anatomy). — Under this head it is intended to give a connected and concise account of the *descriptive anatomy* of the several elements of the venous system, referring the reader to those articles which treat of the regional anatomy of the body, in which will be found the application of the subject in its practical bearings, in so far at least as the large venous trunks are concerned.

The veins connect the capillary vessels with the heart, one of their functions being, to bring back to the central organ of the circulation the blood which has been distributed over all parts of the body: they are naturally divided into two classes.

1. The *veins* which concur to form the two *venæ cavæ*, and which thus communicate with the right auricle of the heart; these constitute the *systemic venous system:* and

2. The *veins* which commence in the capillaries of the lungs, and finally discharge their contents into the left auricle: these represent the *pulmonary venous system.*

These two classes of veins differ from each other in the nature of their contents, no less than in their modes of termination, for whilst the systemic veins contain dark-coloured, and essentially venous blood, the office of the pulmonary veins is to convey red or arterial blood from the pulmonary capillaries, where it has been re-oxygenated, to the left auricle of the heart. *Valves* are not found in the veins of the pulmonary system, whilst they are very abundant in many of the systemic veins.

The *cardiac veins* constitute a small system apart from that of the general venous system, for not having any communication with the venæ cavæ or with any of their branches, these veins open by a separate orifice into the right auricle of the heart.

Neither can the *portal veins* be included in any general description of the venous system. These veins emanate from the stomach, intestines, spleen, and pancreas, and unite to form one large vessel, the *vena portæ*, which entering the liver, branches out in every direction through that organ after the manner of an artery, and thus constitutes *the system of the vena portæ.*

From the capillaries of the portal vein in the liver, another series of veins is derived, which coalesce and form larger and larger trunks, like the systemic veins generally, and ultimately, to the number of three or four, issue from the liver at its thick margin, and join the inferior vena cava. These last-mentioned veins are termed hepatic veins, or venæ cavæ hepaticæ, and the function to which they are subservient in the economy, is that of re-conveying into the general venous system, the blood which has been diverted to the liver by the ramifications of the portal vein.

1. The Pulmonary Veins.

These veins commence in the capillaries of the pulmonary lobules, and by successive junctions with adjacent branches enlarge in size, whilst they diminish in number. They traverse the lungs in company with the subdivisions of the bronchial tubes and of the pulmonary arteries, the number of venous ramifications being identical with that of the arterial, and finally emerge from those organs, having formed into trunks, each of which corresponds to a lobe of the lungs. There are consequently three venous trunks for the right lung, and two for the left. On the right side the branch from the middle lobe unites with that from the superior; and hence two pulmonary veins, one superior to the other, are usually found in the root of each lung, where on both sides they are placed below but on a plane anterior to the pulmonary artery and bronchial tube. In the substance of the lungs the relative position of these parts is different, for there the branches of the veins are behind, whilst those of the artery are in front, the bronchus being interposed between both.

The four pulmonary veins then perforate the pericardium, and after a short course enter the most posterior part of the left auricle, those of the left side opening very close together, and not unfrequently by a common orifice.

Within the pericardium these veins are invested by its serous membrane, but on their anterior surfaces only. In passing to their destination, the right pulmonary veins lie behind the right auricle of the heart.

II. The Systemic Veins.

The veins of this system will be described in the following order.

A. The veins which form the *vena cava superior*, and which are derived from the head, face, neck, thorax, and upper extremities.

Amonst these the veins of the parieties of the thorax (*azygos veins*), and those of the spinal column (*rachidian veins*), are remarkable as serving to connect the branches of the superior with those of the inferior vena cava.

B. The veins which form the *vena cava inferior*, and which convey the blood from the lower extremities and from the pelvic and abdominal cavities. The *portal veins* are an adjunct to this system.

C. The proper veins of the heart (*cardiac veins*), which arise in the substance of that organ, and open by a separate trunk into the right auricle.

A. The Veins which form the Vena Cava Superior.

These are constituted by the veins, 1. *Of the head and face;* 2. *Of the neck;* 3. *Of the upper extremities;* 4. *Of the thorax.*

1. *Veins of the head and face.** — The *superficial veins* of the head and face unite to form three principal trunks, which are placed on the anterior, lateral, and posterior aspects of the cranium; *anteriorly* is seen the

Facial vein. — This vein originates in the frontal region from numerous interlacing branches, which usually give rise to one large vein on each side (*frontal vein*), which is joined by branches from the upper lid (*palpebral*) and root of the nose, and by the *supra-orbital vein;* sometimes there is but one frontal vein placed in the mesial line, and dividing into two branches, which descend one on either side of the nose. The frontal vein continues its course in the sulcus along the inner margin of the orbit under the name of *angular vein*, accompanying the artery of the same name, and receives numerous branches from the orbit, by which a close connexion is maintained between the circulation on the exterior of the cranium and that of the cerebrum itself. At the lower margin of the orbit the angular becomes the proper facial vein, which passes downwards and outwards in an almost direct course to the anterior edge of the insertion of the masseter muscle.

The facial vein consequently has a much shorter extent than its corresponding artery, to the outer side of which it is invariably placed; it passes beneath the zygomatic muscles, and lies on Steno's duct, just where the latter is about to penetrate between the fibres of the buccinator muscle.

The facial vein receives the following *branches.* Veins from the alæ nasi, the *coronary, buccal, infra-orbital,* and *masseteric* veins; and also several large *communicating veins* (*deep facial* or *alveolar*) from a venous plexus which is lodged in the pterygoid space.

Having passed below the ramus of the jaw, the facial vein enters the digastric space, which it traverses from above downwards and backwards, and lies beneath the platysma myoides and on the submaxillary gland (which consequently is interposed between the facial vein and artery); this vein next passes across the external carotid artery to terminate in the internal jugular vein, having been previously joined by a large branch of communication from the temporo-maxillary vein. In its course through the digastric space the facial vein receives (a), *the ranine vein*, which comes from the inferior surface of the tongue, passes backwards by the side of the frænum, and accompanies the hypoglossal nerve, between the mylo-hyoid and hyo-glossus muscles; (b), *the satellite vein of the gustatory nerve*, which is derived from a plexus of superficial veins on the dorsum of the tongue, and communicates freely with the preceding (*Cruveilhier*); (c), the *submental vein*, which arises in the sublingual gland; and (*d*) several *palatine veins* which are derived from a venous plexus encircling the tonsil.

In many instances the facial vein unites with the proper lingual veins, and thus forms a common trunk, which throws itself into the internal jugular; into this common trunk the superior thyroid, pharyngeal, and temporo-maxillary veins, will in such a case be frequently found to open.

On the *lateral* region of the head are placed the trunks of the temporal and internal maxillary veins.

* The veins of the head may be divided into two sets, those which ramify on its exterior and those which occupy its interior; the former will alone be noticed in this place. The latter, which are represented by the cerebral veins and sinuses of the dura mater, are described in Article Nervous Centres (Dr. Todd), Vol. III. 631. Intermediate to these two systems are the veins of the bones of the head (the diploic veins), which, by their inosculations with both, maintain a free communication between the superficial and deeper seated veins. For a description of the diploic veins, see Art. Bone, Vol. I. p. 436.

The *temporal vein* is formed by the union of two branches, which represent the superficial and middle temporal arteries.

The *superficial temporal veins* form a wide-spreading network of vessels on the lateral aspect of the scalp, which communicates with the frontal veins in front, with the occipital behind, and with the temporal veins of the opposite side across the vertex.

The *middle temporal veins* arise in the substance of the temporal muscle, where they are joined, behind the external orbital process, by branches from the orbit: these veins, by their union, form a branch which is placed at first between the temporal muscle and fascia, but subsequently perforates the latter immediately above the zygoma, and forms with the superficial temporal vein a common trunk, which enters the parotid gland, and unites with the internal maxillary vein.

Internal maxillary vein. — In the pterygoid space the branches of veins which correspond to those given off in the same region by the internal maxillary artery, viz. the *inferior dental, deep temporal, pterygoid*, and (according to Cruveilhier) the *middle meningeal veins* (*venæ comites* to the middle meningeal artery, which communicate in the cranium with the inferior cerebral veins), unite to form a great venous *plexus* placed between the pterygoid muscles, which communicates freely, as has been mentioned, with the facial vein. Arising from this plexus, the internal maxillary vein passes backwards along with its artery, between the ramus of the jaw and the internal lateral ligament of the temporo-maxillary articulation, and entering the parotid gland joins the temporal vein; by the union of these branches the external jugular vein is formed. Many anatomists give to the upper portion of the venous trunk, formed in the manner which has just been described, the name of *temporo-maxillary vein*, by others it is designated *posterior facial*, names which are applied to it until it has emerged from the parotid gland, where, according to these authorities, the proper external jugular vein commences.

The *temporo-maxillary vein* (or that stage of the external jugular vein which is contained in the parotid gland) is joined by the branches which accompany the *transverse facial* and *posterior aural* arteries, and sends off a large *communicating branch*, which unites with the facial vein.

The temporo-maxillary vein is situated more superficially than the external carotid artery, which it separates from the plexiform ramifications of the portio dura nerve.

On the *posterior* region of the head is found the *occipital vein.* The ramifications of this vein are spread over the posterior portion of the scalp, and correspond very accurately to the terminal branches of the occipital artery; the trunk which they form likewise accompanies that of the artery, passes with it beneath the splenius and sterno-mastoid muscles, and joins the internal jugular vein *below* the digastric muscle; less frequently it unites with the external jugular vein. Opposite the mastoid process, the occipital vein is joined by several branches from the mastoid region, one of which passes through a canal in the bone (mastoid hole), and communicates directly with the lateral sinus of the dura mater.

2. *Veins of the neck.* — The most remarkable of these are the *internal* and *external jugular*, and the *vertebral veins.*

External jugular vein. — This vessel is the principal channel of the *superficial* venous circulation of the neck. Its direction is downwards and slightly outwards, and it extends from the lower margin of the parotid gland to the subclavian vein. Crossing the sterno-mastoid obliquely, the external jugular vein descends parallel to the posterior edge of that muscle, through the supra-clavicular space, and lies on the deep cervical fascia, by which it is separated from the omohyoid muscle, brachial plexus, and subclavian artery. Finally, the vein passes forwards through an opening in the fascia cervicalis, and joins the subclavian vein. Several of the nerves of the cervical plexus are related to this vein; many of their branches cross it as they descend the neck; and the largest of the three ascending branches of the plexus, the nervus auricularis magnus, is parallel to the vein and to its outer side, as it lies on the sterno-mastoid muscle.

Throughout the entire of its extent the external jugular vein is covered by the fibres of the platysma myoides, which cross its direction obliquely forwards and inwards. This vein is furnished with *two sets of valves*, one of which is placed at its entrance into the subclavian vein, and by this circumstance the external jugular is distinguished from all other veins of the head or neck, in none of which are valves found to exist.

The *branches* which the external jugular vein receives are the following: first, several *large veins from the posterior region of the neck;* one of these, which from its superior size, and also from its position, may be distinguished by the name of *posterior jugular vein*, descends from beneath the trapezius muscle, through the postero-superior triangle of the neck, and joins the external jugular vein a little below its centre. Lower down this latter vein receives, secondly, the "venæ comites" of the superior and posterior scapular arteries. By its anterior surface the external jugular vein receives; thirdly, *muscular branches*; fourthly, a communicating branch, which passes beneath the sterno-mastoid muscle, and joins the internal jugular vein; and *sometimes*, fifthly, the anterior jugular vein.

Anterior jugular vein. — This vein is but seldom absent, although its size is subject to much variety; in general its development is inversely as that of the external jugular trunk, to which it is to be regarded as supplemental. The branches of origin of the anterior jugular vein are derived from several small muscular and cutaneous veins of the supra-hyoid region, which generally communicates with the facial veins. Thus formed, this vein passes down by the side of the larynx along the anterior margin of the sterno-mastoid muscle, beneath which it passes, a little above the clavicle, to join the internal jugular vein, close to the junction of the latter with the subclavian vein.

The anterior jugular vein, in its course down the neck, communicates freely with the internal and external jugular veins, and sometimes terminates by opening into the latter.

It receives branches from the larynx, and sometimes from the thyroid gland.

Not unfrequently the veins of opposite sides are connected by a *transverse branch*, which crosses the trachea immediately above the sternum, and receives the terminations of some of the inferior thyroid veins, and of one or two subcutaneous veins from the thorax.

Internal jugular vein. — The blood which has circulated through the brain and sinuses of the dura mater, is returned by the great lateral sinus to the internal jugular vein, which extends from the posterior part of the foramen lacerum posterius, to the root of the neck, where on each side it forms the vena innominata, by its union with the subclavian vein.

Its direction is strictly vertical.

At its commencement this vein presents an oval dilatation (*sinus*, or gulph of the internal jugular vein), which is lodged in the jugular fossa, and into which the *inferior petrosal sinus* of the dura mater opens. The internal *jugular vein* is placed posterior, and external, to the internal carotid artery, (the lingual, glosso-pharyngeal, and pneumogastric nerves intervening,) and rests upon the anterior surface of the rectus capitis lateralis muscle; but as the vein is traced downwards, it will be found, a little below the base of the skull, to lie parallel with, and to the outer side of, the internal carotid; the spinal accessory nerve here descends upon the anterior surface of the vein. Subsequently, the internal jugular vein enters the sheath of the common carotid artery, along with the vagus nerve, and preserves the same relative position to that great vessel as it did to its internal branch. At the root of the neck the vein of the right side intersects, at right angles, the front of the first stage of the subclavian artery; on the left side, the vein, whilst it is anterior, is at the same time parallel, to the thoracic stages of the subclavian and carotid arteries.

Collateral branches of the internal jugular vein.—Opposite the cornu of the os hyoides, the internal jugular vein is joined by (a) the *facial vein*, and sometimes by (b) a large *communicating branch from the temporo-maxillary vein*, by which its size is sensibly augmented; above the os hyoides, it receives (c) the *pharyngeal vein*, derived from a venous plexus on the sides and back of the phanynx; (d), the *proper lingual veins*, two in number, "venæ comites" of the lingual artery, the course of which they accurately follow: the lingual veins, as has been already stated, sometimes form a trunk of considerable size, by uniting with the facial vein *; and (e), the *occipital vein*, which has been described in the preceding page. Below the level of the os hyoides, the internal jugular vein receives (f) a *laryngeal branch*, which escapes from the larynx through an opening in the thyro-hyoid membrane; (g), the *superior thyroid veins*, "venæ comites" of the superior thyroid artery, and which emanate from the superficial and upper portions of the thyroid gland: these occasionally terminate in the anterior jugular vein, or in the common trunk of the facial and lingual veins when it is present; and (h) the *middle thyroid veins*, which pass out from the lower part of the lateral lobe of the gland, and join the most inferior portion of the internal jugular vein.

The vertebral vein. — The vertebral vein arises by muscular branches, which are deeply placed at the base of the skull, in the vicinity of the foramen magnum, and first exists as a distinct trunk in the foramen of the transverse process of the atlas, where it is joined by two communicating branches, one of which passes through the posterior condyloid foramen, and opens into the great lateral sinus, whilst the other is derived from the occipital vein.

The course and relations of the vertebral vein, from this to its termination, are identical with those of the cervical stage of its corresponding artery, which it accompanies through the foramina in the transverse processes of the cervical vertebræ. On issuing from the foramen of the sixth vertebra, it is joined by the veins which accompany the arteria cervicalis profunda and the arteria cervicalis superficialis. Lastly, the vertebral vein usually passes behind the subclavian artery on the right side, and in front of that vessel, on the left side, to terminate in the vena innominata. Sometimes, though rarely, the vertebral ends in the internal jugular vein.*

The vertebral veins anastomose very freely with the *spinal veins*, as well with those which are within the spinal canal, as with those which are external to the vertebræ, by means of small branches which enter the foramina, by which the cervical spinal nerves issue.

3. *Veins of the upper extremity.* — These veins are arranged in two series, a *superficial* and a *deep*; both of which are provided with valves, but the deep veins the most abundantly.

Superficial Veins. — In the fore-arm and hand these veins are distributed with great minuteness in the subcutaneous areolar tissue, and anastomose freely with one another; but their larger branches chiefly occupy the *radial* and *ulnar* (the lateral) aspects of the fore-arm.

The *radial* or *external superficial veins* emanate from numerous venules on the thumb and dorsum of the fore-finger, and are joined

* In considering the distribution of the veins of the tongue, it may be observed that there are two *superficial* or *submucous veins*, (the *ranine vein*, and the *satellite vein of the gustatory nerve*) corresponding to the subcutaneous veins in the limbs, by which the blood is returned when the *deep veins* (proper lingual) are compressed during the contractions of the organ.

* Vide Art. Subclavian Artery, Vol. IV. pp. 815. and 822.

in the fore-arm by many cutaneous branches from either side. Opposite the elbow joint these tributaries have ended in one vessel of considerable size, the *cephalic vein*, which, being joined by a branch from the median vein (*median cephalic*), ascends between the biceps and supinator longus muscles, follows the outer margin of the biceps, traverses the interspace between the pectoralis major and the deltoid, and ultimately having arrived in the subclavicular triangle, bends over the upper edge of the pectoralis minor, penetrates the thin expansion of the "fascia clavicularis" (*ligamentum bicorne*), and enters the axillary vein immediately beneath the clavicle. In some instances a branch is continued upwards from the cephalic vein, which passes over the clavicle and communicates with the external jugular vein.

The ulnar or internal superficial veins have their origins from veins which ramify on the dorsum of the hand and of the two inner fingers, one of which from the little finger has been long known as the "*vena salvatella;*" others arise anteriorly from subcutaneous veins on the front of the wrist. In the vicinity of the elbow both sets of branches unite to form one principal trunk, the *basilic vein*, which is reinforced almost at the moment of its formation by the *median basilic vein*, a branch of very considerable size from the median.

The *basilic vein*, now much enlarged, ascends along the inner margin of the biceps muscle, parallel to the brachial artery, but more superficially than that vessel, (for the deep fascia intervenes,) until it arrives opposite the centre of the arm, when it pierces the brachial aponeurosis, and joins one or other of the *venæ comites* of the brachial artery. In a few instances the vein ascends as high as the axilla, and entering that space joins the trunk of the axillary vein. The superficial veins in the front of the upper part of the fore-arm unite to form a short trunk termed *median vein*, which by its lateral branches connects the radial and ulnar superficial veins; near the bend of the elbow the median vein receives a large *communicating branch* from the venæ comites of the brachial artery, and terminates by dividing into two very considerable veins, termed *median basilic* and *median cephalic veins* respectively: the latter passes obliquely upwards and outwards, over the tendon of the biceps, and joins the cephalic vein; the former, which is the largest, inclines inwards, and in its course to join the basilic trunk passes across the brachial artery, separated from it only by the "semilunar fascia" of the biceps tendon.

The *deep veins of the upper extremity* accompany the ramifications of the larger arteries chiefly, which in the lower as well as in the upper extremity, are invariably attended by *two veins*, one on either side, hence called *venæ comites;* transverse branches at short intervals maintain a free communication between these vessels.

The *venæ comites of the ulnar artery* are derived from veins which correspond to the *digital* arteries, and which form a *superficial palmar arch* of veins, which at its outer extremity receives branches from the deep radial veins, through which the venæ comites of the radial and ulnar arteries are brought into communication with each other. The associate veins of the *interosseous* artery unite with the venæ comites of the ulnar artery.

The *venæ comites of the radial artery* commence from the *palmar interosseal veins*, which form a *deep palmar arch* across the heads of the metacarpal bones, and are joined by veins from the muscles of the thumb, and by branches of the superficial arch which follow the course of the arteria superficialis volæ. The venæ comites of both the radial and ulnar arteries receive numerous tributaries from the veins of the adjacent muscles, and ultimately unite to form the

Satellite veins of the brachial artery. — The brachial venæ comites are joined by veins which correspond to the branches of the brachial artery in the arm (superior and inferior profunda and anastomotica magna), and also by the basilic vein. At the lower part of the axilla, these veins, by their union, form the axillary vein.

The *axillary vein* returns all the blood from the upper limb: it is formed by the union of the brachial venæ comites (with one or other of which, in the arm, the basilic vein is continuous), whilst the cephalic vein joins it near its termination. Like its accompanying artery, the axillary vein consists of three stages, and its relations to surrounding parts are identical with those of that vessel. The vein is placed internal and anterior to the artery throughout its entire course. When the arm is abducted, the vein becomes inferior.

In addition to the cephalic vein, the axillary trunk receives numerous branches which correspond to those of the axillary artery, viz., the *circumflex* and *subscapular veins*, the *alar*, and the long, superior, and acromial *thoracic veins*.

The axillary is the last vein of the upper extremity, as we approach the heart, in which *valves* exist: at the lower edge of the first rib it becomes continuous with the subclavian vein.

Subclavian vein. — This great vessel extends from the axillary vein to the inner margin of the scalenus anticus muscle, where it unites with the internal jugular vein, to form the vena innominata. The subclavian vein therefore corresponds to the second and third stages only of the subclavian artery; and, as the direction of the vein is nearly transverse, whilst that of the artery describes an arch, it necessarily follows that the former vessel is much shorter than the latter. On both sides of the neck the scalenus anticus muscle, and the phrenic and pneumogastric nerves, are, interposed between these associated vessels. The subclavian vein is related *anteriorly* to the subclavius and sterno-mastoid muscles, to the clavicle, supra-scapular artery, platysma, and superficial structures of the neck, and *rests upon* the first rib, the scaleni muscles, and the phrenic nerve, which descends between the vein and the scalenus anticus muscle. Contrary to what is observed in the case of the axillary and of most other veins of large size, the branches which join the subclavian vein do not correspond to those which are given off by the subclavian artery. The *collateral branches* of the subclavian vein, are the external and internal jugular veins; the former joins it on the outer, and the latter on the inner side of the sterno-mastoid muscle. The subclavian vein not uncommonly receives the vertebral also, although, as has been stated, this vein is most frequently a tributary of the brachio-cephalic trunk.

Brachio-cephalic veins. (*Venæ innominatæ*, Meckel.) — These veins, one on each side, are formed by the union of the internal jugular with the subclavian vein; they are apparently of the same size, but are contrasted in other essential particulars, as they are examined on the right and left side: thus they will be found to differ from each other in length and in direction, as well as in their connexions with surrounding parts, as also in the number of collateral branches which they respectively receive.

The *right vena innominata* is comparatively short, and nearly vertical in direction; it is placed behind the cartilage of the first rib, and is related externally to the right pleura and internally to its corresponding artery, the arteria innominata; the vein and artery however are not in close apposition, and the right pneumogastric nerve is found in the interval between them, but deeper than both; filaments of the cardiac nerves also are interposed between them.*

The *left vena innominata*, more than twice as long as the preceding, traverses the upper part of the anterior mediastinum almost horizontally from left to right, but at the same time with an obliquity downwards and slightly forwards. It is placed behind the first bone of the sternum, from which it is separated by the sterno-hyoid and sterno-thyroid muscles, and by the thymus gland; and bending across the three primary branches of the aorta, slightly overlaps the anterior surface of the arch itself towards the right side. Immediately below the cartilage of the first rib and on the right side of the mesian line, the innominate veins unite to form the superior vena cava.

Collateral branches. — The *vertebral* is in general the only vein which terminates in the right vena innominata, for although it does occasionally occur that the inferior thyroid and internal mammary veins join the vena innominata on their respective sides, yet in the great majority of instances these veins terminate differently on the right and left side: on the left they almost invariably open into the corresponding vena innominata, whilst on the right they as constantly open into the vena cava superior. It is not very uncommon for the left vena innominata to receive all the inferior thyroid veins; and the left superior intercostal vein, which is usually connected by a large collateral branch with this vein, sometimes, but more rarely, terminates directly in that vessel.

Inferior thyroid veins. — Although generally described as consisting of two principal trunks, one for each side, these veins very often consist of as many as four or more branches, which, arising from a plexus of veins in the interior of the thyroid gland, emerge from its lower border and descend on the front of the trachea, covered by the deep layer of fascia and by the infra-hyoid muscles, to open into the left vena innominata. These veins lie in a well-defined triangular space of much surgical importance, which is bounded on the one side by the innominata, and on the other by the left carotid artery, whilst its third side, which represents the base of the triangle, is defined by the lower margin of the thyroid body: the apex is constituted by the convergence of the arteries which form its sides, to the arch of the aorta; and in this latter direction, the space above described is somewhat encroached on by the left vena innominata. Sometimes the thyroid veins of opposite sides unite to form an arch across the trachea, and in some few instances they open into the transverse branch of communication which sometimes unites the anterior jugular veins of opposite sides.

Internal mammary veins. — These, which constitute "venæ comites" to the trunk of each internal mammary artery, are formed by branches which correspond with those which emanate from that vessel. Very frequently the two vessels unite in a single trunk, which ends, as has been stated, in the vena innominata on the left side, and in the vena cava on the right.

Vena cava superior. — This great vein receives all the blood from the head and neck, and from the upper extremities; it is formed by the union of the two brachio-cephalic veins, and extends from the lower margin of the cartilage of the first rib on the right of the sternum, to the upper and posterior part of the right auricle of the heart where it terminates. Shortly after its formation, the superior vena cava enters the pericardium. That portion of the vein which is without the pericardium (and which is of very small extent) is invested by a sheath of the fibrous layer of that membrane, whilst its intra-pericardial stage is completely invested by the serous membrane, which it serves to convey to the surface of the heart. In its entire course this vein describes a curve, the convexity of which is related to the right pleura with the intervention of the pericardium, whilst the concavity touches the aorta; the pericardium is anterior to it, and the pulmonary artery of the right side passes behind it. The principal collateral branch of the thoracic vena cava is

* At the moment of its formation the right vena innominata is placed anterior, and inferior, to the first stage of the subclavian artery; between them, however, we find the mammary artery, and the phrenic and pneumogastric nerves.

the *great azygos vein*, which joins that trunk at the moment of its entrance into the cavity of the pericardium.

*Azygos veins.**— The azygos veins and their tributaries (which are described by Cruveilhier amongst the superficial rachidian veins) constitute a remarkable system which is of great importance, as it assists in maintaining the circulation through the spinal system of veins, and at the same time connects the branches of the superior with those of the inferior vena cava.

The veins of the azygos system usually consist of three principal trunks, the *greater* and *lesser azygos veins*, and the *left superior interc stal vein.*

The vena azygos major commences in the lumbar region, by the union of several branches from the upper *lumbar veins*, through which it communicates with the inferior vena cava. Sometimes the azygos vein receives a branch *directly* from that vessel, and frequently another from the *renal vein.*

After a very short stage in the abdomen, the great azygos vein enters the thorax through the aortic canal in the diaphragm, and ascends on the vertebral column to the right of the aorta, from which it is separated by the thoracic duct. Having arrived at the third dorsal vertebra, the vein now changes its direction, and passing forwards and to the right side, leaves the posterior mediastinum, arches over the right bronchus, and descends to terminate in the superior vena cava, where that vessel is about to enter the pericardium.

The vena azygos major is joined by all the *intercostal veins* of the right side, and by the *lesser azygos vein*, through the medium of which it communicates with the lower intercostal veins of the left side also. Two or three of the middle intercostal veins of the left side open directly into the great azygos vein, it likewise communicates very freely with the left superior intercostal vein.

The lesser azygos vein (or *left* or *inferior azygos vein*), likewise has its origin in the lumbar region, from some of the upper lumbar veins on the left side of the spine; it anastomoses with the neighbouring veins which ramify on the surface of the vertebræ, and is connected, more frequently even than the greater azygos vein, with the corresponding renal vein (Breschet). The lesser azygos vein enters the thorax, either through the aortic canal in the diaphragm, or by perforating its left crus along with the left splanchnic nerve, ascends on the left side of the spine, as high as the fifth or sixth dorsal vertebra, where, crossing the front of the spinal column, behind the aorta, to terminate in the great azygos vein.

The veins from the five or six lower intercostal spaces terminate in this vessel. In some instances there is no venous trunk corresponding to that above described, in which case the left intercostal veins cross the spinal column behind the thoracic aorta, to join the great vein of the right side, which, under these circumstances only, is appropriately termed "azygos."

The left superior intercostal vein (*left superior azygos vein*) is formed by the union of the three or four superior intercostal veins of the left side. Its course is subject to some variety, but it always serves to establish a connexion between the azygos system and the deep veins of the neck. In many instances this vein passes *upwards*, and opens into the left vena innominata, but more frequently it descends, increasing in size as it approaches its termination in the great azygos vein. Sometimes the left superior intercostal vein terminates in the azygos minor.

There is sometimes a similar branch on the *right side*, which corresponds to the right superior intercostal artery; this vein is always inferior in size to that of the left side, and, like it, terminates in the great azygos vein.

The bronchial veins are the "venæ comites" of the bronchial arteries, from the capillaries of which they are derived, and which they accompany throughout the lungs. They leave the root of the lung, having formed into two or three trunks, and terminate, *on the right side*, in the superior vena cava, or in the great azygos vein, and on the left side in the left superior intercostal vein, or in the azygos minor.

In the pelvis the *middle* and *lateral sacral veins* represent the *azygos system;* they communicate freely with the veins in the sacral canal, and with the vesical and hæmorrhoidal plexuses, and end in the common iliac veins. The sacral veins thus establish a communication between the general venous system and the system of the vena portæ.

There are *no valves* in the azygos veins, although they exist in great numbers in their tributaries, the intercostal veins.

*Veins of the spine.** (*Rachidian veins:* Breschet.)—These veins, imperfectly known to Chaussier, were first accurately described by Dupuytren and Breschet†; they have been comprehensively arranged by Cruveilhier, who includes, under the head of spinal veins, a larger portion of the venous system than the author first quoted. By Cruveilhier the veins of the spinal system are divided into—A. The *superficial* or *extra-spinal*, and B., the *deep* or *intra-spinal veins.*

A. *The superficial veins of the spine* are subdivided into the anterior and the posterior.

* As these veins have already been described in an article specially devoted to the subject, they are but briefly noticed in this place, and only in so far as was necessary to carry out the design of giving a continuous description of the elements of the venous system. Vide Art. Azygos (Dr. Harrison), Vol. I. p. 364.

* Such of the *veins of the spine* as are situated in the interior of the spinal canal, are described in the Article Nervous System (Dr. Todd), at page 629, Vol. III. of this work; any other than a brief notice of the subject in this place is, therefore, unnecessary.

† Essai sur les Veines du Rachis, 4to. Recherches Anatomiques sur le Système Veineux, fol. avec Planches.

1. *The anterior superficial spinal* (or rachidian) veins, include, according to this authority, the *vena azygos major*, the *vena azygos minor*, the trunk of the *right and left superior intercostal veins*, the *lumbar* and *ilio-lumbar veins*, and the *lateral* and *middle sacral veins*.

2. *The posterior superficial spinal veins*, "form an exceedingly complicated network, the meshes of which surround the spinous processes and laminæ, and the transverse and articular processes of all the vertebræ."

B. *The deep* or *intra-spinal* veins comprise the following: —

1. The veins of the bodies of the vertebræ;
2. The great anterior longitudinal veins or sinuses (Willis);
3. The posterior spinal veins and plexuses; all these are *external* to the "theca vertebralis:" and
4. The veins of the spinal cord itself; *internal* to the theca vertebralis.

Superficial spinal veins. — The *anterior superficial spinal veins* have been already described as constituting a part of the azygos system.

The *posterior superficial spinal veins* (the *dorsi-spinal veins* of Dupuytren and Breschet) are derived from the muscles which fill the vertebral grooves, and thus cover the laminæ and the spinous and transverse processes with a series of anastomosing vessels. In the neck they form a complicated plexus, from which proceed two large veins (*posterior jugular*, Cruveilhier), which communicate freely with the vertebral veins, and join the venæ innominatæ.

From the numerous venous circles and plexuses formed by the "dorsi-spinal" veins, *communicating branches* are given off, which perforate the ligamenta subflava, or pass through the intervertebral foramina, and unite freely with the deep spinal veins.

Deep spinal veins. — 1. *Veins of the bodies of the vertebræ: (veines basi-vertébrales*, Breschet), [vide *Fig.* 361. Vol. III. p. 630.], are contained in bony canals in the bodies of all the vertebræ, and are analogous to the diploic veins of the cranium. The basi-vertebral veins originate in the canallated tissue of the bone, and form larger trunks, which converge towards the posterior surfaces of the bodies of the vertebræ, where the orifices of the bony canals in which they are contained are very apparent; on emerging from the vertebræ these veins form a plexus (*transverse plexus*) interposed between the bones and the posterior common ligament of the spine, and from which veins pass laterally to terminate in the anterior longitudinal sinuses. Some of the smaller venous canals pass forwards to open on the anterior surface of the vertebral column, where they anastomose with the superficial veins.

2. *The anterior longitudinal sinuses*, Willis: (*grandes veines rachidiennes longitudinales antérieures*, Breschet), [vide *Fig.* 360. p. 630.] —These extend the entire length of the vertebral column, under the form of two longitudinal veins situated within the spinal canal, along the external margins of the posterior common ligament, and consequently between the bodies of the vertebræ and the dura mater, (hence sometimes termed meningo-rachidian veins). Opposite every vertebra these longitudinal vessels are connected to each other by the *transverse plexus* of the basi-vertebral veins, whilst externally they communicate, by means of branches which pass through the series of intervertebral foramina, with the numerous veins which ramify on the exterior of the spinal column, viz., the vertebral, azygos, intercostal, lumbar, sacral, &c. These longitudinal venous channels are neither parallel to each other, nor are they of uniform dimensions; opposite the bodies of the vertebræ they are most closely approximated, whilst corresponding to the intervertebral foramina they are widely separated, as if drawn outwards by the branches which are here connected with them. Each longitudinal sinus, or "venus plexus," (for occasionally two or more veins enter into the formation of these channels on each side,) might therefore be described as formed of "a series of plexiform arches, which embrace the pedicles of each vertebra, have their concavity directed outwards and their convexity inwards, and the extremities of which anastomose together opposite the intervertebral foramina, where they communicate with the branches on the outside of the spine."* According to Breschet, interruptions occasionally occur in different parts of these longitudinal channels, a circumstance which still further authorises this description, in which *each* venous arch is regarded as a separate trunk, communicating with its fellows of the opposite side, and also with similar branches above and below.

3. *The posterior deep spinal veins* (*veines longitudinales rachidiennes postérieures*, Breschet) are likewise situated in the interior of the spinal canal, between the posterior surface of the dura mater and the front of the laminæ. They there form a close interlacement of vessels (*posterior intra-spinal plexuses*) which is most remarkably developed in the upper part of the canal. These veins and plexuses are joined by the posterior superficial spinal veins (*dorsi-spinal veins*), and they communicate with the anterior longitudinal sinuses by numerous small lateral branches.

4. *The proper veins of the spinal cord* (*medulli spinales*, Breschet) are small tortuous vessels, which form an irregular plexus upon both surfaces of the medulla spinalis between the pia mater and the arachnoid membrane; they communicate through the foramen magnum with the petrosal sinuses or cerebellar veins, and give off small branches which pass through the foramina with the spinal nerves to establish communications with the several *extra*-spinal veins. The veins of the spinal cord are apparently the "venæ comites" of the proper spinal arteries.

"*The veins of the spine* may be regarded, in reference to the general circulation, as establishing an unbroken communication be-

* Cruveilhier's Descriptive Anatomy, vol. ii. p. 808.

tween the veins of all parts of the trunk, so that we can suppose one of the venæ cavæ to be obliterated without the venous circulation being interrupted. The greater azygos itself, which is generally regarded as the principal means of communication between the two venæ cavæ, is not, however, necessary, when we consider the arrangement of the anterior and posterior spinal plexuses. Thus, I have sometimes seen the inferior, and sometimes the superior vena cava, obliterated without any apparent increase in the diameter of the vena azygos, and, what will perhaps be thought surprising, without œdema either of the upper or lower extremities.

"Supposing the vena cava ascendens to be obstructed from the entrance of the hepatic veins down to the renal veins, the blood would then flow back by the lumbar veins into the plexuses contained within the spinal canal; through these plexuses it would ascend to the vertebro-costal (intercostal) veins, from thence to the azygos veins, and through them into the superior vena cava.

"If all the jugular veins were obliterated, the venous circulation in the head would still continue, and would be carried on through the spinal veins." *

B. Veins which form the Inferior Vena Cava.

The veins which unite to form the inferior vena cava transmit the blood which is derived from the lower extremities and from the viscera of the pelvis and of the abdomen.

1. *Veins of the lower extremities.* — The veins of the lower, like those of the upper extremities, are divided into a *deep* and a *superficial set;* they are likewise provided with valves, which are most numerous in the veins of the former class.

Superficial veins of the lower extremities. — The small veins, which in great numbers exist in the subcutaneous cellular tissue of the dorsum of the foot, unite to form two principal trunks termed *saphenous.* These are placed, the one on the inner, and the other on the posterior aspect of the leg.

Internal or long saphena vein. — This vein first exists as a distinct vessel a little below the ankle joint, in front of which it ascends and passes along the inner surface of the leg, at the distance of half an inch from the inner margin of the tibia. At the knee it lies behind the internal condyle, superficial to the tendons of the sartorius, gracilis, and semitendinosus muscles, and continuing to ascend on the internal and anterior surface of the thigh, gains the "saphenic opening" in the fascia lata, through which it passes backwards to end in the femoral vein, at the distance of about an inch below Poupart's ligament.

In this long course the saphena vein receives many *cutaneous branches,* and also several *communicating veins* from the deep vessels. In the thigh, it is joined, near its termination, by a large branch, which comes from the back of the limb, and by two or three veins which are derived from the anterior and external surfaces of the thigh. These latter pursue a direction upwards and inwards, and thus cross anterior to the femoral artery, so that they are liable to be injured by the incisions made to expose that artery. The trunk of the saphena vein itself is seldom thus endangered, as it ascends on a plane internal to the artery. Shortly before its termination, the saphena vein is enveloped in the meshes of the cribriform fascia, where it is joined by three *cutaneous* veins from the parieties of the abdomen, — viz. the *superficial pubic,* the *superficial circumflexa ilii,* and the *superficial epigastric* veins. When, from any cause, the circulation through the inferior vena cava is obstructed, those veins become remarkably enlarged and tortuous.

The internal saphena vein is accompanied, from the ankle to the knee, by the internal saphena nerve. The *valves,* in its interior, vary from two to six sets.

Communicating branches pass between this vein and the deep veins of the leg and thigh; they are most numerous in the leg, where they connect the saphena with the anterior and posterior deep tibial veins.

Posterior or external saphena vein. — The external saphena vein is formed by the union of several branches from the outer side of the foot, and ascends into the leg behind the outer ankle. Inclining inwards and upwards, it gains the centre of the back of the leg, passes superficial to the groove between the heads of the gastrocnemius muscle and enters the poplitæal region. Opposite the line of flexion of the knee-joint, this vein passes through a small round opening in the poplitæal fascia, and joins the poplitæal vein about its centre. This vessel, sometimes called the *short saphena vein,* is accompanied in part of its course by the posterior saphena nerve. It is usually furnished with two *valves,* which are found near the termination of the vessel. This vein communicates but rarely with the deep veins of the leg.

Deep veins of the lower extremity. — In the lower, as well as in the upper extremities, the deep system of veins is represented by the "venæ comites" of the larger arteries. The satellite veins of the posterior tibial artery are derived from the *deep plantar veins* (*external and internal*). At the upper part of the leg the posterior tibial veins are joined by the satellite veins of the peroneal, and subsequently, at the lower edge of the poplitæus muscle, by those of the anterior tibial artery. By the union of these is the trunk of the poplitæal vein formed.

The *poplitæal vein.* — This vein is of large size, owing to the number and magnitude of the branches which it receives; it is joined by the *tibial veins,* by the *external saphena,* by the *articular,* and, lastly, by *muscular veins* of large size (*sural*) from the calf of the leg.

The poplitæal vein is placed posterior to its artery below, posterior and a little external to that vessel, at the upper part of the poplitæal

* Cruveilhier's Descriptive Anatomy, vol. ii. p. 810.

space. It is consequently situated between the artery and the posterior tibial nerve.

The *valves* in this vein are four or five in number. Its coats are stated by Cruveilhier and others to be of more than ordinary thickness.

The *femoral vein* is the continuation of the poplitæal, which latter vessel, having passed through the tendinous opening in the adductor muscles, enters the thigh, and becomes femoral. In the lower third of the thigh the femoral vein and artery (enclosed in a common sheath) are contained in "Hunter's canal," the vein lying, as in the ham, posterior and external to the artery. In the centre of the thigh the vein is placed directly behind the artery; but throughout its upper third the two vessels lie side by side, and in close connection, the vein being the more internal. A thin, fibrous septem derived from the sheath which surrounds them passes backwards, and separates these vessels at this part of their course. The point of the aneurism needle is apt to be entangled by this partition, in conveying a ligature round the femoral artery, if care be not taken to keep the instrument on its outer or arterial side, whilst at the same time the sheath is kept tense. At the highest point of its course, just where it is about to pass beneath Poupart's ligament, the femoral vein constitutes the external boundary of the crural ring, and would therefore necessarily bear the same relation to the neck of any hernial tumour which may have descended through this aperture. In its course through the thigh, the femoral vein is joined by numerous *muscular branches*, also by the *profunda vein*, about an inch and a half below the crural arch, and, lastly, by the *internal saphena vein*.

Its *valves* are from three to five in number.

Beneath Poupart's ligament the femoral becomes continuous with the external iliac vein.

The *external iliac vein*, whilst it accompanies the external iliac artery, and holds the same relation to surrounding parts as that vessel, is nevertheless differently related to its artery on the right and left side. As these vessels lie on the horizontal ramus of the pubis, their relative positions at both sides is the same, the vein being placed internal to the artery. On the *left side* this relation does not alter, and the vein lies on the inner side of the artery throughout its whole course; on the *right side*, however, the vein, in its ascent, passes first behind the artery, and then appears slightly to its outer side.

The *internal circumflex ilii* and the *two deep epigastric veins* join the external iliac vein at the commencement of its course immediately above Poupart's ligament. The former holds a remarkable relation to the external iliac artery, for it crosses that vessel at right angles to its anterior surface, and thus separates the artery from the fascia transversalis.

The *internal iliac vein* is formed in the cavity of the pelvis by the union of the veins which correspond to the numerous divisions of the internal iliac artery, — viz. by the *glutæal*, *sciatic*, *internal pudic*, and *obturator* veins, all of which arise *external* to the pelvis; and by numerous branches from the viscera contained *within* the pelvis, and which are remarkable for their plexiform arrangement. Of these, the *vesical veins* form a plexus which surrounds the neck of the bladder, and the prostate gland (*vesico-prostatic plexus*), receives the blood from the *dorsal veins* of the penis, and communicates freely with the *inferior hæmorrhoidal veins*. *In the female* a similar plexus receives veins from the clitoris and the labia, and in addition there are two others, still more remarkable for their development, — the *vaginal plexus*, which surrounds the vagina near its commencement, and communicates with the vesical plexus in front, and with the hæmorrhoidal veins behind, and the *uterine plexus*, the veins of which are scarcely apparent except during gestation, and which communicate with the ovarian veins.

In *both sexes* the lower extremity of the rectum is surrounded by the ramifications of the *hæmorrhoidal plexus*, the blood of which is returned to the internal iliac vein by the middle and inferior hæmorrhoidal veins. This plexus likewise communicates freely with the *superior hæmorrhoidal veins*, which unite with the inferior meseraic veins, and so constitute a part of the portal system.

In all these vessels *valves* exist in great numbers, although none occur in the great trunks in which they terminate.

The internal iliac vein on each side is internal to its corresponding artery.

The *common iliac veins* are formed by the union of the external and internal iliac veins. The junction takes place opposite the sacro-iliac symphisis. These veins exhibit on each side some interesting anatomical peculiarities.

The *right common iliac vein*, nearly vertical in its direction, is placed posterior and external, to its corresponding artery.

The *left common iliac vein*, larger than the preceding, and nearly transverse in its direction, lies internal, and inferior, to its corresponding artery, and crosses behind the common iliac artery of the right side.

The common iliac veins usually unite upon the intervertebral substance between the fourth and fifth lumbar vertebræ, to form the vena cava inferior. The junction occurs to the right of the mesial line, and inferior to, as well as to the right of, the angle of bifurcation of the aorta.*

The *collateral branches* of the common iliac veins are the following: —

(*a*) The *ilio-lumbar vein.*—This vein arises in the iliac fossa, by radiating branches, which

* The junction of the venæ innominatæ to form the superior vena cava, as well as that of the common iliac veins to form the inferior vena cava, occurs on the right of the mesial line of the body. In the former instance, the uniting veins are found on a plane anterior to the arterial trunks which they accompany; whilst in the latter they lie behind them.

correspond in their distribution to those of the artery of the same name, and communicate freely with the lower lumbar and sacral veins.

(*b*) The *middle sacral vein.* — A single trunk placed on the sacrum in the middle line, which communicates inferiorly with the vesical and hæmorrhoidal plexuses, and on each side with the adjacent lateral sacral veins. It usually opens into the left common iliac vein, but sometimes terminates more symmetrically, by bifurcating and giving a branch to either common iliac vein.

(*c*) The *lateral sacral veins.* — These anastomose very freely with the *middle* sacral and glutæal veins, and with veins in the sacral canal, before terminating in the common iliac veins.

Inferior vena cava. — (Vena cava ascendens.)

This vein, the largest in the body, since it returns to the heart all the blood which is circulated below the diaphragm, is formed by the junction of the common iliac veins, just as the superior cava is constituted by that of the venæ innominatæ. The abdominal vena cava passes upwards in front of the lumbar vertebræ, behind the liver and on the right side of the aorta. At first the inferior vena cava and the aorta are in close contact; but as they ascend, the vein inclines forwards and to the right side, so that in the vicinity of the diaphragm these great blood-vessels become more and more remotely related to each other, and finally, the thoracic duct, the vena azygos, the right splanchnic and sympathetic nerves, the right crus of the diaphragm and the Spigelian lobe of the liver intervene between them. The *anterior relations* of the inferior vena cava are the following: the peritoneum, the mesentery, the inferior portion of the duodenum, the pancreas, the commencement of the vena portæ, and the liver, which latter sometimes forms a complete canal for the cava. *Posteriorly,* the inferior cava corresponds to the vertebræ, to the psoas muscle, and to the right renal and right lumbar arteries: *externally,* it is related to the right kidney.

The inferior vena cava is not uniform in its dimensions, for it presents two remarkable *dilitations* in its course, *the first* where it is joined by the emulgent veins, and *the second,* opposite to its junction with the venæ cavæ hepaticæ.

Having passed behind, or through, the liver, the vena cava is transmitted through the "foramen quadratum" of the diaphragm, and at the same time penetrates the fibrous layer of the pericardium, which is here intimately connected with the cordiform tendon of the diaphragm. Above the diaphragm the vena cava bends abruptly to the left, and, after a very short, and almost transverse course within the pericardium, during which it is invested on its anterior surface by the serous membrane, terminates by entering the most posterior and inferior portion of the right auricle; the axis of its opening is directed upwards, backwards, and to the left side. There are no valves in this vessel.

Collateral branches. — Besides the common iliac veins, which are its formative roots, the inferior vena cava receives the following, viz., the *renal, spermatic,* (*ovarian* in the female), *supra renal, lumbar, inferior phrenic,* and *hepatic* veins.

(*a*) The *renal veins* are of great size, and pass transversely to join the cava; the *left* is the longest; it passes in front of the aorta to arrive at its destination, and is joined by the *left spermatic, vein.*

Both renal veins arise in the cortical substance of the kidneys by small radicles, which unite into larger vessels: these pass between the "pyramids," and so gain the hilus, where they lie in front of their accompanying arteries.

(*b*) The *suprarenal,* or capsular veins, are more numerous than the arteries of the same name; there are usually three veins on each side, and but one artery. The veins are the *superior,* which joins the inferior phrenic, a *middle,* which unites directly with the vena cava, and an *inferior,* which opens into the renal vein of its own side.

(*c*) The *spermatic veins* originate in the testis, and pass through the mediastinum testis. On entering the cord they receive veins from the epididymis, and assume a loose plexiform arrangement (*plexus pampiniformis*). The spermatic veins, now four or five in number, pass along the cord, and traverse the inguinal channel with the vas deferens and spermatic arteries. At the internal abdominal ring the spermatic veins leave the vas deferens and accompany their corresponding arteries, lying behind the peritoneum and in front of the psoas muscle. Continuing to ascend, these veins cross the ureters external to the common iliac arteries, approximate to one another, and finally terminate, that of the right side in the vena cava, and that of the left side in the left renal vein.

In the abdomen there is either one spermatic vein, on each side, or two veins which freely communicate by short transverse branches, and unite in one common trunk before terminating.

In the female these vessels are represented by the

Ovarian veins, which form a plexus between the layers of the broad ligament, and terminate in the same manner as the spermatic veins in the male.

(*d*) *Lumbar veins* (*lumbo-vertebral veins*). — There are four or five pairs of lumbar veins which are in every respect analogous to the lumbar arteries from the aorta: they arise by *muscular branches* in the lumbar region, and in the parieties of the abdomen, where they are connected with the epigastric veins, and on both sides pass behind the psoæ muscles to open into the cava close to one another: the veins of the left side cross the spine behind the aorta. The lumbar veins communicate very freely with the venous system of the spinal canal, with the ilio lumbar veins below, and with the commencement of the azygos veins superiorly.

(*e*) The *inferior phrenic veins* are derived from the diaphragm, and correspond accurately to the phrenic arteries from the aorta.

The *hepatic veins* may be considered as forming an adjunct to the portal venous system, in connection with which they will be briefly noticed.

PORTAL VENOUS SYSTEM.—One remarkable class of the veins of the abdomen, those of the chylopoietic viscera, do not terminate directly in the vena cava, but unite to form a large trunk — *vena portæ*, which enters the liver, and, branching out like an artery (hence the name *vena arteriosa*), forms a capillary system in the substance of that organ.

The trunk of the *vena portæ* is formed by the coalescence of several large veins, which return the blood from the stomach, spleen, pancreas, and from the entire of the intestinal tract, with the exception of the lower part of the rectum, many of the veins of which open into the internal iliac vein, as has been already mentioned.

The veins which form the porta are the following: — the *superior* and *inferior mesenteric*, the *splenic*, *gastric*, *duodenal*, and *pancreatic*, *veins*. All these are destitute of *valves*.

1. *Inferior mesenteric vein.* — The veins of the upper portion of the rectum (*superior hæmorrhoidal veins*), sigmoid flexure of the colon, and descending colon, unite to form this vein, which ascends behind the inferior transverse portion of the duodenum and the pancreas, and opens into the splenic vein. By means of the free communications which exist between the inferior hæmorrhoidal veins and the hæmorrhoidal and vesical plexuses, the system of the vena portæ is connected with that of the general systemic circulation.

2. The *splenic vein* arises in the spleen, and, accompanying the splenic artery (which lies superior to the vein), follows a transverse direction from left to right, and passes behind the pancreas to unite with the superior mesenteric vein.

Besides its *proper splenic* roots the splenic vein receives the veins which correspond to the "vasa brevia," as also the *epiploic*, *pancreatic*, and *inferior mesenteric* veins.

The *gastric veins*, of which the *coronary* (*coronaria ventriculi*) is the most considerable, likewise terminate in the splenic vein.

3. The *superior mesenteric vein* (*grande mesaraïque*, *Cloquet*) receives the venous capillaries from the duodenum and all the small intestines, also from the ascending and transverse portions of the colon, and passes behind the pancreas, where it unites with the splenic vein. The superior mesenteric vein corresponds to the artery of the same name, and is placed anterior and to the right of it.

The *trunk of the vena portæ*, formed by the union of these two great veins (splenic and superior mesenteric), is placed at first behind the head of the pancreas, to the right of the spinal column, and a little to the left of the inferior vena cava: it next ascends, with an obliquity backwards and to the right side, between the layers of the gastro hepatic omentum to the transverse fissure of the liver; after becoming slightly enlarged (*sinus of the vena portæ*), it there divides into two branches, which pass horizontally into the right and left hepatic lobes respectively. Its principal *anterior relations* are the following: the head of the pancreas and the duodenum, the hepatic artery, and the ductus choledochus; to the two latter vessels it is related, whilst traversing the gastro-hepatic omentum; it is surrounded by branches of lymphatic vessels and of the *hepatic plexus* of nerves.

The portal veins, and their subdivisions in the liver, surrounded by a prolongation from the capsule of Glisson, are contained within the "portal canals," and are each accompanied by a branch of the hepatic artery, and by a branch of the hepatic duct. From these arise the *vaginal* and *interlobular* branches, which, by their inosculations, form plexuses which are similarly named. The interlobular veins surround the lobules on their capsular surfaces, and ultimately, having been joined by the terminal branches of the hepatic artery, enter the lobules (forming the *interlobular veins*), and terminate by inosculating with the *intralobular* (hepatic) *veins*: "this plexus interposed between the *interlobular portal veins* and the *intralobular hepatic vein* constitutes the venous part of the lobule, and may be called the *lobular venous plexus*." — (*Kiernan.*)

"The portal vein collects the venous blood from the chylopoietic viscera, and then circulates it through the lobules: it likewise receives the venous blood, which results from the distribution of the hepatic artery to the structures of the liver: these two sources of supply constitute the *two origins* of the portal vein, the *abdominal origin* and the *hepatic origin*." *

The blood conveyed to the liver by the branches of the vena portæ is conveyed back again into the general circulation by the hepatic veins.

Hepatic veins. — These veins arise in each lobule, from the lobular venous plexus, by a vein termed, from its position, *intralobular*. The intralobular veins unite with others termed *sublobular*, which, by their coalescence from the venæ cavæ hepaticæ, these latter, usually four in number, leave the liver at its thick margin, and open into the vena cava inferior, where that vein passes between the Spigelian and right lobes of the liver.

C. CARDIAC VEINS.

The proper veins of the heart form a separate system of small extent, which communicates with the right auricle of the heart by the great cardiac vein. Their principal trunks are thus distinguished:

1. *Great cardiac vein* (*anterior* or *great coronary vein*). — This vein commences on the anterior surface of the heart, near its apex, and ascends in the anterior interventricular groove, as far as the base of the ventricles, where, bending abruptly to the left, it gains the back of the heart by passing round the left margin of the organ in the deep horizontal groove between the left auricle and the left

* Vide Vol. III. p. 168., Art. LIVER.

ventricle. Still observing a transverse direction, the vein in its farther course, passes from left to right, crosses the upper extremity of the posterior interventricular groove, and finally opens into the posterior surface of the right auricle to the right of the mesial line.

Before its termination, the great coronary vein presents a bulbous dilitation (*sinus of the coronary vein*). Its orifice in the right auricle, which is protected by a special valve (*valve of Thebesius* or *lesser Eustachian valve*), is situated between the great Eustachian valve and the right auriculo venticular opening.

Posterior cardiac vein (*posterior* or *lesser coronary vein*).—The lesser cardiac vein arises near the apex of the heart, on its posterior surface, and ascends in the posterior interventricular groove, where it is joined by muscular branches from either side. Finally, it terminates in the great coronary vein when that vessel forms its ampulla in the deep groove above the base of the ventricles.

Several small veins, which belong exclusively to the right ventricle, ascend along the right border of the heart, and, curving round in the groove between the right ventricle and right auricle, likewise join the great coronary vein — one of those which has long been distinguished by the name of the "*vein of Galen*," is stated to communicate, frequently, by a separate opening, with the right auricle.

Other veins of extreme minuteness (*venæ minimæ* or *veins of Thebesius*) are described as opening separately at various points into either auricle. Their existence is denied by some anatomists.

(*B. Geo. M'Dowel.*)

VERTEBRAL COLUMN.—(See Supplement.)

VESICULA PROSTATICA. (Syn. *Sinus prostatæ; sinus pocularis; utriculus prostaticus; vesicula prostatica media seu spuria; uterus masculinus;* Corpusculum Weberianum.) The tubular structure indicated by this name is a part of the male sexual apparatus in Mammalia. It lies between the lower ends of the seminal ducts, and opens between them, by a special aperture, into the commencement of the urino-genital canal: an opening which has been usually, but not quite correctly, viewed as an immediate process of the urethra.

In Man, in whom alone it was recognised until a few years ago, it is a little vesicle, which is covered by the prostate. A similar form and arrangement recurs in many mammalia: but others exhibit very considerable deviations. Sometimes it is altogether absent, or is but very rudimentary; while in other instances it is of considerable size. Its relation to the prostate is equally variable; but even in man it is only superficial, being solely due to its local arrangement.

On these grounds, the name "vesicula prostatica," which at any rate merely applies to its human anatomy, cannot always be used. We prefer, therefore, to use that of "the *Weberian organ* or corpuscle," a name which has been lately proposed in order constantly to recall the great service which an eminent anatomist has rendered to our knowledge of this remarkable structure.

E. H. Weber was the first who recognised the great morphological import of this organ, and who adduced proofs that in man and the male mammalia it is the rudiment of an organ which, by a great development in the female individual, determines the form and physiological relations of her generative apparatus. Weber* explained the vesicula prostatica as the analogue of the uterus, and gave it the name of the uterus masculinus.

We would willingly accept this denomination, if Weber's view were quite correct. But since we shall hereafter point out that this never specifies the full morphological value of the vesicula prostatica, but is, in many cases, erroneous, we prefer the nomenclature already mentioned. Our examination of the Weberian corpuscle is divisible into three sections. The first regards its variations of form; while the second considers the question of its possible functional import; and the third has for its object to determine the morphological value of this structure.

I. Anatomy. — The Weberian corpuscle occurs only in the class Mammalia, where we meet with a greater complication of the sexual apparatus than in any other group of the Vertebrata. Thus the Mammalia are the only vertebrate animals whose females possess a real vagina and uterus. What we designate by this name in some other Vertebrata cannot be regarded as morphological equivalents of the vagina and uterus of Mammalia.

Man.—The Weberian corpuscle is a small flask-shaped vesicle, with a rounded blind end and a narrow neck directed downwards, placed on the hinder wall of the urethra, under the verumontanum, and covered by the prostate. The middle lobe of this gland limits the upper end of the corpuscle. The length varies, but is commonly 3, 4 or 6 lines; the breadth at the upper end is 2 lines, but it sometimes attains a more considerable size. Thus Adams† mentions an instance in which it had a length of an inch, and by its upper end, which projected free, was placed upon the dorsal surface of the middle lobe of the prostate. And in the hypospadian described by Theile‡; its size was yet more considerable ($1\frac{1}{2}$ inches).

The constricted neck sometimes forms half of the whole corpuscle, and is, according to Huschke§, sometimes separated from the

* Annot. anat. et physiol. zu Kretzschmar's Diss. inaug. circa lineam physiol. morbor. Lips. 1836. Amtlicher Bericht über die Versammlung Deutscher Naturforscher in Braunschweig, 1842, p. 65. Zusätze zur Lehre vom Bau und den Verrichtungen der Geschlechts-organe (in den Abhandl. der Fürstlich Jablonowskischen Gesellschaft), Leipzig, 1846.

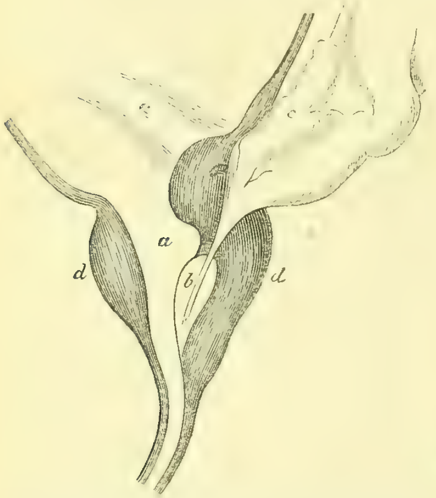
† See article Prostate Gland, Vol. IV. p. 151.

‡ Müller's Archiv für Physiologie, 1847, p. 23. Tab. III. fig. 4., copied by Adams, loc. cit. fig. 106.

§ Soemmerring's Lehre von den Eingeweiden. Leipzig, 1844, S. 409.

upper dilated part by a kind of constriction. The under end opens by a small elongated oval aperture (of $\frac{1}{3}$ to $\frac{1}{2}$ line) on the anterior declivity of the verumontanum. The orifices of the two ejaculatory ducts* lie right and left of the opening, at a very small distance from it, usually somewhat higher, yet never quite symmetrical: they are sometimes close to it, or somewhat behind it. These ducts pass up the sides of the Weberian organ, and receive it between them, being bound up with it by areolar tissue.

Fig. 873.



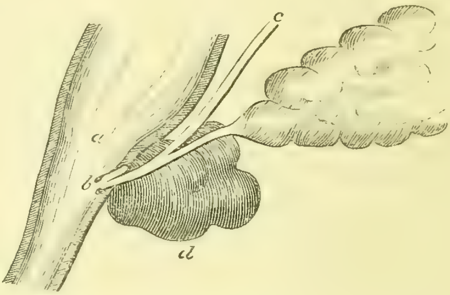
Perpendicular Section of the Weberian corpuscle in Man (copied from Weber's Zusätzen.)
a, Urethra; *b*, Weberian corpuscle; *c*, vas deferens, with vesicula seminalis; *d*, prostate.

In the Weberian corpuscle of two new-born infants, H. Meckel † found a special variety of structure. It became thinner in its ascent, so as to be only permeable by a hog's bristle, and ended as a solid thread, which separated by bifurcating.

Morgagni ‡ was the first who accurately described the Weberian organ, which he also probably discovered. Of fifteen human bodies which he examined with this object, he found it in fourteen. It is possible that in the one remaining case he overlooked it, since it sometimes happens that its mouth is but small, or is even altogether deficient, as Huschke has frequently ascertained it in healthy and robust suicides. Nevertheless it is not improbable that in some cases there is a complete absence of the Weberian corpuscle; the less so that we sometimes verify such differences in other animals. In two of these fifteen cases, Morgagni found that the utriculus, instead of opening by a special aperture, communicated with one of the ejaculatory ducts. But at all events this is a rare anomaly, which has been since observed by Adams only.* In a case mentioned by Hyrtl †, there was a simultaneous deficiency of both vesiculæ seminales, and the ejaculatory ducts descended into the upper end of a single receptacle, which was one inch long and seven lines broad. But though Hyrtl and Theile regarded this structure as certainly an uterus masculinus, and thus as a Weberian organ; yet the insertion of the ejaculatory ducts at the upper end is a circumstance which contradicts their view. As we shall hereafter show, such a connection is a morphological impossibility. Even where an immediate communication between the vasa deferentia and the Weberian corpuscle exists (as is normally the case in the hare), it occurs only at the inferior extremity of the latter organ.

Quadrumana. — In the Apes a Weberian

Fig. 874.



Weberian corpuscle of Inuus Cynomolgus, as seen by a perpendicular Section.
a, Urethra; *b*, Weberian organ; *c*, vas deferens with seminal vesicle; *d*, prostate.

corpuscle appears very general. It here incloses a small, narrow and flat canal, which above has a blind extremity, and scarcely possesses a greater width than at its lower end. Its length is about two lines. Its mouth, in the uro-genital canal, is surrounded as with a wall by an annular swelling, which has some resemblance to a small os tincæ, and in which one may also, generally, distinguish an anterior and posterior lip. Immediately behind this opening are the mouths of the ejaculatory ducts, the lower ends of which are apposed to the hinder wall of the corpuscle, and are covered by the prostate.

As far as my researches go ‡, the above description will apply to the Weberian organ in all Apes. At least I have found it thus in *Inuus Cynomolgus* (in whom it was formerly described by Bergmann §), in *Inuus nemestrinus*, *Cynocephalus Maimon*, and a species of Harpale (*Harpale Iacchus*?) which, with all the animals I examined, was placed at my

* See Prostate, Vol. IV. fig. 103.

† Zur Morphologie der Harn- u. Geschlechtswerkzeuge. Halle, 1848, S. 48. Tab. II. fig. 23.

‡ Advers. Anat. IV. Animadv. 3. Venet. 1762, p. 110.

* Adams, loc. cit. p. 153.

† Oesterreiche Medic. Wochenschrift, 1841, S. 45.

‡ Zur Anatomie u. Physiologie der Geschlechtsorgane. Göttingen, 1847, S. 99.

§ Wagner's Handworterbuch der Physiologie, Bd. III. Abth. 1. S. 130. Anmerkung.

disposal from the stores of the Physiological Institute of this place.

Volitantia. — Among the Bats I have found a Weberian organ hitherto only in *Vespertilio murinus*. Here it is a small corpuscle, scarcely one line in size, between the ejaculatory ducts. It is covered by the prostate, and opens at the usual place by a small and scarcely visible aperture. In *Plecotus auritus* I have sought after it in vain. So also in *Galeopithecus variegatus*, where the points of opening of the two seminal ducts are placed close together upon a small and elongated verumontanum.

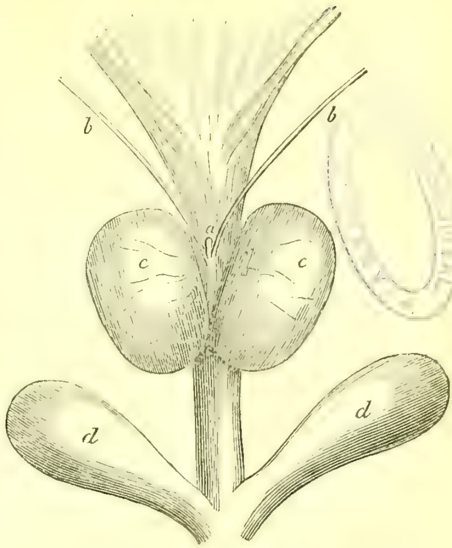
Insectivora. — The *Erinaceus Europæus Talpa Europæa**, *Sorex araucus*, and *Macroscelides Rozeti* were examined: only in the last is a Weberian organ present. It is a roundish flask, which is proportionately of a very considerable size, being fully one line long, and quite as broad at the end. It opens, by means of a short constricted neck, into the uro-genital canal between the two seminal ducts. The prostate, which consists, as in the Sorex, of two compound gland-tubes, lies in front of the utriculus, and close to it, but without covering it. The thickened lower ends of the seminal ducts receive it between them, and are united to it by areolar tissue.

Feræ.—In the *dog* and the *cat* the Weberian organ forms, as Weber has shown, a long small bladder of some lines in size, which is, for the most part, placed before the prostate in a fold of peritoneum stretching between the two ejaculatory ducts. There is no opening into the urethra.

The description of Weber † certainly holds good in many instances, yet not in all. I have examined numerous dogs and cats, and have very frequently found, instead of a vesicular structure, a simple solid cylindrical cord, which I have regarded as an obliterated rudiment of the organ. In many individuals even this could not be detected. I also found the Weberian organ as a solid cord in the *fox* and *leopard*. The striped *hyæna*, on the contrary, possesses an elongated flask-shaped Weberian corpuscle; but it, together with the ends of the seminal ducts, is hidden between the two kidney-shaped halves of the large prostate.‡ The latter are only fused posteriorly; in the larger anterior half they are united by areolar tissue into a common mass. There is no opening into the uro-genital canal, and I have found none in any of the beasts of prey examined.

The Weberian organ of the *otter*, which Leydig* has described, is of unusual form, and much more considerable development. It lies between the urinary bladder and the two seminal ducts, and consists of a body about six lines in length and proportional breadth, the upper free end of which is drawn out right and left into a long and thin thread lying on the seminal duct. The cavities and their openings could not be examined; but without doubt both were present. The Weberian organ is very similar in the *Meles Taxus*. It is a very considerable cylinder, which measures about ten lines, and rises to the hinder surface of the glandular ends of the vasa deferentia, being very firmly united to them by areolar tissue. The upper end is folded into two horns, only the right of which is permeable to a short distance. The left is, from its root onwards, a solid thin thread, which is closely attached to the

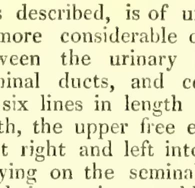
Fig. 875.



Weberian Organ of the Hyæna Striata (reduced to half the natural size.)

a, Weberian organ; *b*, *b*, vasa deferentia; *c*, *c*, prostate; *d*, *d*, Cowper's glands.

Fig. 876.



Weberian Organ of the Badger.

a, Weberian organ; *b*, *b*, vasa deferentia; *c*, thread-shaped horns of the Weberian organ.

* The commencement of the uro-genital canal in the Eimacera and Talpa, forms in an anomalous manner a spacious and defined cavity. Into this cavity the urethra opens, as in the female mammalia, by a narrow slit-shaped aperture. This was described by me some time ago (zur Anatomie, &c., SS. 102. 105.) at which period I erroneously explained the cavity as a male vagina.

† Zusätze, &c. Tab. VII.

‡ The length of the prostate is fully one and a half inches: its breadth is yet larger. Cowper's glands are also of considerable size, two inches long. They have a longly clavate form, and a very thick covering of striped muscular fibres.

* Zeitschrift für Wissentschaftliche. Zoolog. von Siebold u. Kölliker, Band II. S. 49.

corresponding vas deferens. Its cavity is that of a canal, but not so wide a one as might be guessed from the exterior thickness of the body; and it opens by a distinct aperture on the verumontanum.

Pinnipedia. — The genitals of a young male seal, probably *Phoca vitulina*, were examined by me. Here I saw a scarcely visible linear fold, which led to a longish Weberian organ of about two lines in size. The fold lay close behind a small ridge-shaped verumontanum, on which were the orifices of the vasa deferentia, situated close to each other. As in the dog, the organ is situated partly in front of, partly beneath, a prostate, which in form and development also corresponds with that gland in the dog.

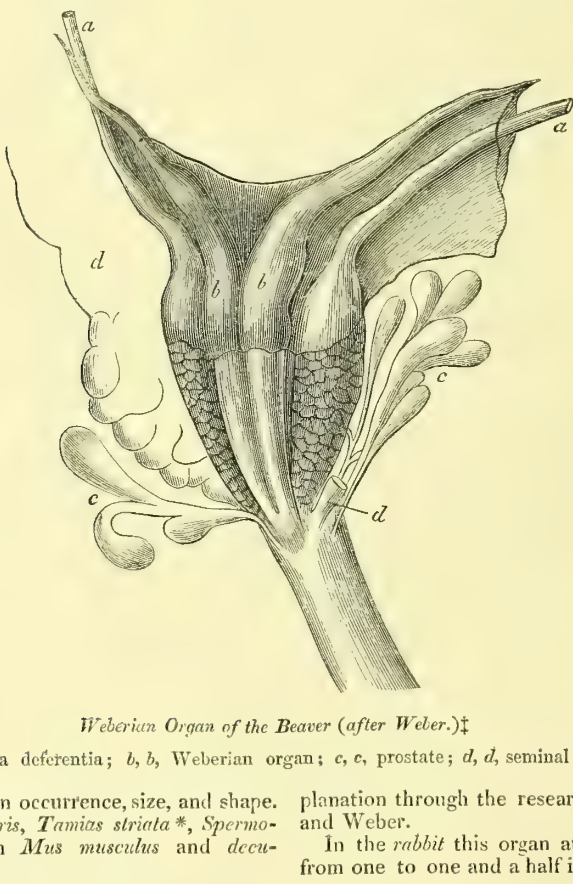
Marsupialia. — In *Didelphys Virginiana* the only animal of this order whose male genitals I had, no trace of the Weberian corpuscle was present.

Rodentia. — The Weberian organ showed great variations in occurrence, size, and shape. In *Sciurus vulgaris*, *Tamias striata* *, *Spermophilus atillus*, in *Mus musculus* and *decumanus*, and *Hypudæus amphibius*, I have looked for it in vain. But certainly the *Myoxus Vitela*, *Dipus Ægyptiacus* and *Cricetus vulgaris* exhibited a single small longitudinally-folded verumontanum, which, from its situation between the two orifices of the vasa deferentia, must have been the opening of a Weberian organ: but this structure iself, on account of its sheer minuteness and hidden situation, eluded the further searches, which were made in only a few individuals.

In *Cavia cobaya* the Weberian organ is, as I described it some time since *, a small roundish vesicle, scarcely a line in size, which has a bilobed extremity, and, as in *Macroscelides*, a constricted neck, which opens into the uro-genital canal between the two seminal ducts. The Weberian organ of the rabbit and hare is very much larger. It was formerly known to the older zootomists under the name of the azygous seminal vesicle †, and has only received a more accurate description and explanation through the researches of Huschke and Weber.

In the *rabbit* this organ attains a length of from one to one and a half inches, so that it

Fig. 877.



Weberian Organ of the Beaver (*after Weber.*)‡

a, a, vasa deferentia; *b, b,* Weberian organ; *c, c,* prostate; *d, d,* seminal vesicles.

* The Cowper's glands of this animal are cylindrical structures of very considerable size (almost half an inch long): they have knot-shaped thickenings at their end, and are rolled up in a coil around this extremity. The prostate consists of two large gland lobes which have the form of a hammer.

* Zur Anatomie, &c. p. 104.

† See fig. 281. Art. RODENTIA, Vol. IV. p. 393. (Rymer Jones.)

‡ This engraving is copied from the "Zusätze," &c.

projects very far, behind the urinary bladder. It has the form of a flask, and in its anterior half, which is compressed somewhat flat, it has a breadth of five to six lines. Its base is bilobed, as if drawn out into two lateral short and rounded horns. Its mouth in the uro-genital canal is wide (about one line), yet not round or linear, but rather placed across, and somewhat arched in shape, as if bent around the swelling of the verumontanum. In new-born individuals the organ is much smaller, scarcely three lines long; but it is otherwise exactly similar. In the male *hare* it is always smaller. In one example it measured five lines, and was devoid of horns at the base; but these are sometimes little developed in the rabbit also. But the most extraordinary circumstance about the utriculus of these animals is this, that it receives the ejaculatory ducts. In all other instances, these open independently, by its sides, into the uro-genital canal; but here, departing from this rule, they open into the undermost part of the Weberian organ, at a short distance (in the new-born rabbit half a line, in the adult two lines) above its orifice previously described. They occupy the anterior wall of the organ, on which they course downwards, and each terminates in a small papilla. In *Lagomis* the same arrangement seems to occur. At least Pallas* states of the *Lagomis ogstona* that the two ejaculatory ducts open together by a common tube, which must doubtless be regarded as a Weberian organ.†

Another very remarkable form of Weberian organ is possessed by the *beaver*. The first information concerning it we owe to Brandt and Ratzeburg‡, who compared this structure, on account of its form, to the uterus bicornis of the female individual, yet without recognising any nearer relation between the two. They regarded it as a kind of supplementary seminal vesicle. Its correct interpretation is due to the acuteness of Weber.§

The Weberian organ is simple only at its lower end, or that which usually opens between the orifices of the two vasa deferentia. Very soon it is split into two horns, which ascend in the peritoneal fold between the two seminal ducts, and finally, after they have dwindled to the form of threads, are apposed to these. Brandt and Ratzeburg were able to follow the terminal threads to the testicles; while in the example which Weber investigated, where the horns measured $2\frac{1}{2}$ inches, they ceased much earlier. The lower half of the horn is of very considerable thickness, as much as four lines, and it encloses a spacious cavity.

Edentata. — The sloth (*Bradypus tridactylus*), the only animal of this class of Mammalia whose genitals I was able to examine, is completely devoid of this organ.

Pachydermata. — Duvernoy* mentions the Weberian organ in the *elephant* as a deep, blind sac, which lay concealed in the verumontanum. In the swine it has been described by Weber. It consists here of a body, which is nine lines in length and almost a line in thickness, and which lies in the peritoneal fold between the two ejaculatory ducts. At its upper end it passes on either side into a yet longer but thinner horn. Leydig, who also mentions the opening of this body into the uro-genital canal, states that, when in the inflated condition, it has the thickness of a goose quill.

In an adult *boar* with hypospadias, I found this organ of yet larger size. The opening, which lay between the points of aperture of the two ejaculatory ducts, and had a length of $1\frac{1}{2}$ lines, led into a cylindrical body, which, gradually dilating to some extent as it passed upwards, finally, after a course of fourteen lines, split into two horns. These were placed against the seminal ducts, and, as cords of areolar tissue, could be followed with the coverings of those tubes to the testicles. In other instances the Weberian organ of the pig experienced a more considerable reduction. Thus in a new-born individual whom I examined, I found only a single solid cord in the middle line of the peritoneal fold between the vasa deferentia; it had neither cavity nor opening into the uro-genital canal.

Solidungula. — The Weberian organ of the *horse*, which is generally of very considerable size, was known to Cuvier†, who referred it to the vesicula seminalis. It has also been frequently described and figured by Gurlt‡ as a median seminal vesicle. The first who recognised its morphological importance was Hausmann.§ With a reference to the older researches of Weber upon the vesicula prostatica of man and the beaver, but before this author had published his later observations on the horse, he explained it as the male uterus. And independently of him, Adams‖ was led to the same result.

The Weberian organ of the horse is a wide tube, which opens into the uro-genital canal by a large opening between the two vesiculæ seminales, the ejaculatory ducts of which it receives by the constricted neck of its lower extremity. In particular instances this opening is, as Leydig observed, divided by a median bridge into two apertures, which lie close to

* Nov. Spec. quadruped. e glirium ordine. Erlangen, 1778, p. 67.

† According to Rymer Jones (loc. cit. p. 393.), the two vasa deferentia in the Agouti also open by a common duct into a cavity of the verumontanum. But since this at the same time receives the excretory ducts of the seminal vesicles, it certainly is not the cavity of the Weberian organ. Probably the same structure is repeated here which I formerly (loc. cit. p. 130.) described in the Cavia, and have recently found in the Dipus.

‡ Medizinische Zoologie. Band I. S. 137.

§ Amtlicher Bericht., &c., loc. cit.

* Cuvier, Leçons d'Anatomie comparée, nouv. edit. t. viii. p. 210.

† Cuvier, Leçons d'Anatomie comparée, nouv. edit. t. viii. p. 176.

‡ Anatomie der Hussaäugethieren, Berlin, 1834, Th. II. S. 99. Anatom. Abbildungen der Haussäugethieren, Berlin, 1844, Tab. 69.

§ According to the communication of Bergmann. Op. cit.

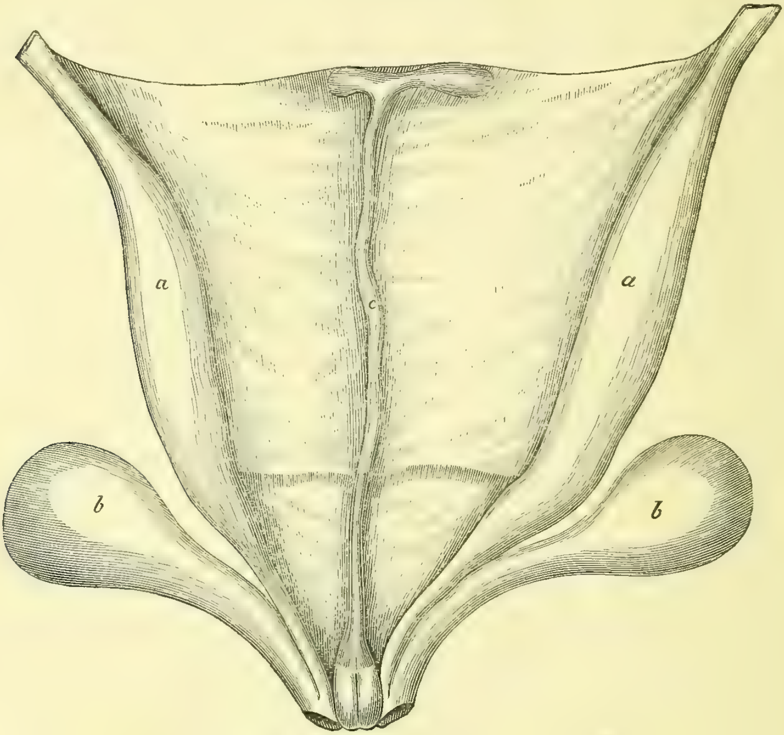
‖ Loc. cit. p. 152.

each other; or it is even, as Weber found it, completely closed. In the same manner Gurlt found that the Weberian organ, instead of opening by a special aperture, sometimes communicated with one or other of the ejaculatory ducts. The lower end of the tube is considerably dilated for a length of 1 to 3 inches. Above, this dilated part generally passes into a narrow cylinder, which sometimes attains a length of 5 to 7 inches, and then divides into two short and usually unequal horns. Not unfrequently this upper part is, as was observed by Leydig and seen by myself, a simple solid thread. In the instance described by Weber the cavity was altogether absent; and an absence of the whole Weberian organ has been observed by Leydig.

In the male *ass* I have also seen a very conderable Weberian organ (*fig.* 878), the existence of which I was first made aware of by Bergmann. It is here a straight canal, four and a half inches long, which ascends in the peritoneal fold between the two ejaculatory ducts, and divides at its extremity into two, much wider, horns. These have blind ends, and a length on the right side of 5, on the left of 9, lines. There is no opening into the uro-genital canal, but the lower end has a vesicular dilatation of four lines in length, and is separated by a longitudinal fold into two blind sacs lying close behind each other.

Ruminantia. — In the *Llama*, which possesses a heart-shaped parenchymatous prostate, I have been unable to find either a median, single, opening into the commencement of the uro-genital canal, or a Weberian organ. But, on the other hand, one finds a very distinct rudiment in the new-born male *deer*.* Here it courses as a single cord-like thread in the peritoneal fold between the two ejaculatory ducts until finally it bifurcates at about an inch from the place of their insertion. It is only during the earlier stage of embryonic life that I have been able to find a cavity and its opening: in the new-born individual the Weberian organ is already obliterated and solid. Some larger and smaller hydatidous vesicles which are found in its course, and especially at the site of its bifurcation, are the only relics of this its earlier condition.

Fig. 878.

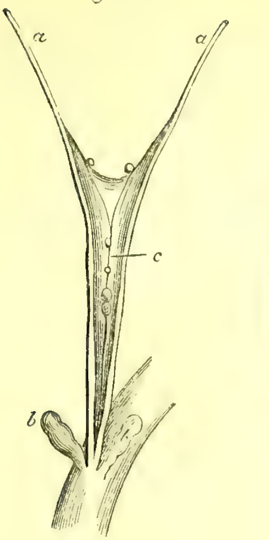


Weberian Organ of the Ass (*reduced in size.*)
a, a, vasa deferentia, with the seminal vesicles, *b, b*; *c,* Weberian organ.

The same form of Weberian organ is repeated in the *goat;* but its development seems here to be very variable. I examined a large number of genitals, which had been preserved some time in spirit. In all, the Weberian organ was of considerable size and development. Nevertheless I have reasons for the conjecture that this is not the rule, and that

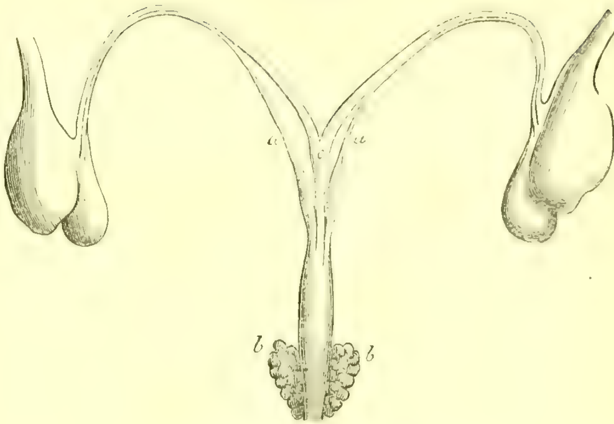
* See my description in the Göttingische Gelehrte Anzeige, 1848, No. 174.

Fig. 879.



Weberian Organ of the Deer.
a, a, vasa deferentia; ***b, b***, seminal vesicles; ***c***, Weberian organ.

Fig. 880.



Weberian Organ of the Goat.
a, a, seminal ducts; *b, b*, seminal vesicles; *c*, Weberian organ.

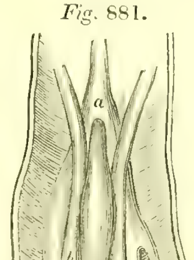
in the majority of he-goats a less complete development of the Weberian organ occurs.

According to my observations the organ consists of a cylindrical body, which ascends between the two seminal ducts, and is strongly united to these by areolar tissue, especially in its inferior half. After a course of an inch and a half it splits into two horns, which are apposed to the seminal ducts, and continue with these to the testicles, where they pass into the covering of the epididymis. In two instances the lower third of the body was dilated into a longish vesicle of about three lines in diameter, while the part above this measured scarcely one line. At the seat of bifurcation it was again dilated, though less considerably. In one individual the middle portion was obliterated so as to form a solid cord. The point of opening into the uro-genital canal is a small linear fold, which is separated by a short interval from the orifices of the vasa deferentia, and is usually placed below, but, in one instance, above them.

The genitals examined were those of either new-born individuals, or of such as were but a few weeks old. In two instances, which were in no way distinguished by a special development of the Weberian organ, the uro-genital canal was wider and shorter than normal, measuring from 2 to $2\frac{1}{2}$ inches long only, instead of about 4 inches, while the penis was smaller, and twisted into numerous zigzags or spirals. But in other respects the male organs were quite perfectly developed; the urethra opened at the extremity of the penis, and the testicles had descended into the scrotum.

In the *sheep* there is no Weberian organ. Even in the new-born individual, neither its opening nor any other indication of it can be found. But in the *bullock* I found immediately under the orifice of the vasa deferentia a small and scarcely noticeable roundish aperture, through which a probe penetrated about two lines in depth, evidently into the tubular cavity of a small Weberian organ, which was covered by the heart-shaped mass of the prostate.

Fig. 881.



Weberian Organ of the Monodon.
a, verumontanum; *b, b*, orifices of the vasa deferentia; *c*, orifice of the Weberian body.

Cetacea. — Some time ago* I described the Weberian organ in the *narwhal* and *dolphin*. It lies in the prostate, beneath the conspicuous

* Zur Anatomie, &c., S. 100.

verumontanum, and possesses a flask-shaped cavity of about one inch in depth. The opening at the lower declivity of the verumontanum is a fissure which has the shape of a horse-shoe curved forwards, while a triangular papilla, which arises from its posterior margin projects into it. In the Monodon the latter is farther separated by a linear fissure. In a dolphin (*Delphinus orca?*) which I examined, the anterior extremity of this papilla was united with the opposite margin; so that the opening was divided into two fissures converging superiorly. In the same way Leydig observed it in *Delphinus phocæna;* while in another individual of the same species I have met with the condition previously described. Possibly in younger individuals of the Cetacea the Weberian organ has a yet greater development. At least Eschricht, who was not aware of the structure just described, states* that, in a male embryo of the *Pterobalæna*, the inferior extremity of both vasa deferentia was connected with a transverse fold, of which the free margins exhibited the appearance of an obliterated cord. From its situation this would about correspond to the lateral horns of an uterus.

II. Physiology.—We, now, proceed to enquire what is the use of this structure, the occurrence and variable forms of which we have hitherto been treating of. It is a general law that the physiological import of an organ stands in a direct relation with its anatomical development. If we regard the Weberian organ in this point of view, we shall soon be convinced, from its absence in many Mammalia, and from the varieties of its development in particular individuals, that its influence upon life cannot be very important.

When Morgagni first discovered the human Weberian organ, he thought that it was connected with the prostate. Its situation made him think it possible that some tubes of the prostate emptied themselves into it, and that it was in a certain manner, like the gall-bladder, a saccular dilatation of the excretory duct of the prostate. But anatomical research soon convinced him that his conjecture was necessarily erroneous. A communication between the prostate and the Weberian organ never exists, and is indeed rendered impossible by an arrangement like that which obtains in the horse, the goat, and the beaver.

According to other views, the Weberian organ has the function of a seminal receptacle. Thus it has received the name of a vesicula seminalis. But we know how prone the earlier anatomists were to this designation, and how they indicated in this manner all those accessories of the male genitals of Mammalia which opened near, or together with, the ejaculatory ducts, without any closer acquaintance with their structure and import. More recent researches † have corrected us on this point. They have shown us that the dependent structures known as the dual seminal vesicles of the vasa deferentia almost always possess a glandular texture, and never, or only occasionally (as in man), contain spermatozoa. It is true that the flask-shaped seminal vesicles of the horse and ass are genuine reservoirs of sperm, — as we may conclude from the fact, that the vasa deferentia open into them, — but as a rule exactly the reverse relation obtains.

But the same anatomical arrangement as that of the vesicula seminalis in the horse may be seen in the Weberian organ* of the hare previously mentioned. On this ground only one might conclude a similar functional import. And the microscope really brings proof that the contents of the Weberian organ are, in this instance, sperm.

But the connection of the excretory duct and the Weberian organ is limited to the hare and lagomys. In all the other Mammalia the two structures open near to each other without any communication. Now if, in spite of this, the Weberian organ has the function of a seminal receptacle, this can only happen by the sperm, which has been previously poured into the urethra, being discharged through the lower aperture of the Weberian organ into its interior.

We will not quite deny the possibility of such an occurrence; but the probability of it seems but small. At any rate a contraction of the muscular layer around the urethra would be necessary thereto; but, without offering any new hypothesis, it would scarcely be possible to perceive why the sperm should thus be sent upwards rather than downwards. The verumontanum alone would not be able to prevent this.

Such considerations would be silenced by direct observation; but hitherto no one has ever met with real semen in the Weberian organ, except in the hare. Morgagni states, that on pressing the human vesiculæ seminales, he has seen sperm exude from the prostatic utricle. But the correctness of this statement is rendered very doubtful by the fact, that the examination was made at a time when the accurate diagnosis of semen was not yet understood. A fluid may certainly have exuded from the Weberian organ, but that it was sperm is very doubtful. It might easily form the contents of the Weberian organ, where, as is sometimes the case, this has an abnormal communication with one or the other vas deferens.

I will not bring forward further arguments against the import of the Weberian organ as a seminal vesicle, such as its little capacity in many instances, &c. They would only prove that such a function is sometimes impossible.

A third theory of the function of the vesicula prostatica has been lately suggested by Weber. According to this view it is a kind of valvular ventricle, by which the urine

* Untersuchungen über die nordischen Wallthiere, Liepzig, 1849, S. 102.

† Leydig, l. c.

* As has been also remarked by Leydig. H. Meckel, on à priori grounds, wrongly denies this connection in the hare.

is hindered from penetrating the vasa deferentia. In order to this, the urine must, like the semen in the previous view, enter into the vesicle, which, distended by it, must by its own pressure close the ejaculatory canals. Hence the same difficulties recur as in the first case. Since the urethra contains urine only during the act of micturition, and is at other times empty and collapsed, this fluid must, even in its passage through the tube by which it is discharged, pass into the vesicula: a fact which is the less supposable, inasmuch as to this end a backward movement of the urine would be necessary. Besides in many cases the situation of the Weberian organ is such that, even if distended by a fluid, it could not possibly operate in such a way. And moreover, even where it might perhaps be possible, it seems unnecessary, since the tumid or papillary margins of the orifices of the vasa deferentia are sufficiently closed by the passage of the urine itself.

One other conjecture of the physiological value of the Weberian organ still remains to us, — viz. that it is a secretory apparatus. It was found by the older anatomists that here and there, for instance in the horse, it was filled with a thick fluid, mostly of a yellow tint. As was previously remarked, this can only be secreted by the coats of the Weberian organ. Morgagni mentioned that the inner clothing of the organ was a mucous membrane, and possessed a glandular texture; and the later researches of Huschke and Leydig have succeeded in verifying a number of small glands therein. These glandules have a different form in the different animals; for instance, in the rabbit they are simply spherical; in the boar they are elongated tubes provided with buds and processes.

Whether such glandules always exist in the Weberian organ must be verified by further careful researches. Leydig could not find them in the dolphin, nor could I in the dog. At any rate they are absent where, as in the deer, &c., the cavity has disappeared.

Exteriorly to this mucous membrane, which possesses a layer of cylindrical cells as an epithelium, there is a layer of smooth muscular fibres, which take the longitudinal direction. In the hare only, in whom they form a considerable layer, especially at the lower end, they are more twisted together. It is evident that this latter arrangement is connected with the import of their Weberian organ as a seminal vesicle. At all events they are thus susceptible of more powerful contractions, which one may produce in the recently dead animal by galvanic and other stimuli for a considerable time. Together with these muscular fibres there is a quantity of areolar tissue with white and yellow fibres. This sometimes predominates, and where the cavity disappears, it seems to occur alone.

It can no longer be doubted that the Weberian organ, at least where it is completely developed, and possesses an internal cavity and an opening, may prepare a secretion; but the nature and physiological import of the secretion are as yet unknown to us. H. Meckel* states, that he once found a clear vitreous mass in the Weberian organ of the rabbit, which from its re-actions was gelatine. Nevertheless it is very improbable that the secretion always consists of this substance, at least if I can judge from its external physical properties.

This secretion may easily be carried away from time to time with the urine or the sperm. Whether it plays any further part — whether it is possibly, like the secretion of the prostate, subservient to the dilution of the semen (as may be conjectured from the arrangement of the Weberian organ in the hare) or to other purposes, we know not. After all, however, the function of the secretion can scarcely be an important one.

III. Morphology. — It is impossible that we should be quite satisfied with what we have learnt above concerning the physiological value of the Weberian organ. Granting that, in some instances, it serves as a seminal receptacle, that in others it delivers up the product of secretion, still its essential import is certainly not thus exhausted. It seems that the application of the Weberian organ to this or that end is but a casual result of its general situation, rather than that it constitutes a sufficient reason for its presence. We are constrained to adopt such a view by the circumstance, that the Weberian organ is frequently devoid of all connection with other structures, and is even sometimes reduced to a ligamentous thread, the functional value of which one cannot imagine.

Thus the Weberian organ takes a rank amongst that class of structures which possess not so much a prominent functional value, as a morphological import; which are necessitated not so much by the actual requirements of life as by the general typical plan of the structure. Should any one deny the existence of such a class of structures, it would only be necessary to remind him of the wing-stumps of many apterous insects, of the bony girdle for the extremities of the blind worm, of the embryonal teeth in the bearded whale. All these are parts which are of scarcely any physiological value to the animals named, although under different circumstances, and in other animals they fulfil the most important functions: they are simply morphological rudiments, which, according to the common architectonic law, are repeated even where they are useless.

But such parts are found, not merely in particular animals and groups, but also especially in the different sexes. Of what use to the male individual are the milk-glands and teats? of what use to the female the well-known rudimentary penis called the clitoris? Are they not the plainest indications that the male and female organs are constructed after a common type, and that it is only by different developments of the same elements that they

* Op. Cit. p. 49.

take their different forms, and with these their different destinies? Careful contemplation leads us to regard the Weberian organ as one of this class of structures. As was previously mentioned, Weber had pointed out, that by its situation and connection with the uro-genital canal, and very frequently (as in the beaver) by its form, it corresponds so completely to the uterus of the female mammalia, that there is every reason for regarding it as its morphological equivalent in the male individual.

According to this view, the difference between the Weberian organ and the uterus is limited to that of a lesser or greater degree of development. In the female individual it becomes the receptacle of the embryo. The physiological task which it thereby undertakes demands a complete development, while in the male individual, in whom it has not such an important functional import, and is only occasionally applied to this or that subordinate purpose, it undergoes a check, or even retrogrades in development. The different degree of this checked or retrograde metamorphosis, depending on its different application, conditionates the difference of its anatomical development. In many male individuals it completely disappears; in others it remains an useless relic of a rudimentary character, while in others it assumes a more considerable size and development.

The form of the receptacle of the embryo, which, despite many varieties, is in general very constant, is connected with its functional import. But the Weberian organ is devoid of so specific an object. What wonder, then, that we find it more freely submitted to the play of the formative process, and that its form and development are even subject to manifold varieties in particular individuals?

The theory of Weber at once gives us a sufficient explanation of the different anatomical circumstances of this notable organ; and in like manner it affords a new and secure basis for the efforts of anatomists to determine the analogy — *i. e.* the common plan of structure — of the male and female organs.

Ever since Aristotle and Galen, vain attempts have been made to discover an indication of the uterus in the male of the Mammalia; and sometimes this structure, sometimes that — now the vesicula seminalis, and now the prostate — has been thus regarded. The explanation given by Weber offers the first satisfactory adjustment, and at the same time promises a sufficient interpretation of the numerous hermaphrodite misdevelopments, or of androgyny. Weber even hints at this (and independently of him Bergmann also), while he subjects the well-known case of Ackermann* to a morphological analysis†, although only with the immediate intention of further supporting his explanation of the vesicula prostatica. He came to the conclusion that the part described by Ackermann as a cystoid uterus, the opening of which into the uro-genital canal was situated close to the efferent apertures of the vasa deferentia, was due solely to a disproportionate enlargement of the vesicula prostatica.

* Infantis androgyni historia et iconographia, Jenæ, 1805. See also Art. HERMAPHRODITISM, Vol. II. p. 709.

† Zusätze, loc. cit. S. 13.

Under such circumstances it is easily explicable why the theory of Weber has received a very general assent. Huschke, Theile, Hausmann, Bergmann, Leydig, and the author in Germany, Duvernoy in France, and Adams in England, have all accepted it, and have sought to give it further stability by new researches. And Leydig* has further shown that the type of the glands imbedded in the wall of the Weberian body completely corresponds with that of the uterine glands in the respective female animals.

H. Meckel† only has expressed himself against the interpretation of Weber, although he so far agrees with it as also to see in the vesicula prostatica a rudimentary structure of chiefly morphological import; but he explains it as being the analogue, not of the uterus, but rather of the vagina. The chief support which he adduces of this theory is the relation of the Weberian organ to the vasa deferentia and the urethra.

It is well known that the older anatomists regarded the vasa deferentia as the structures which, in the female individual, discharge the functions of the Fallopian tubes. Even Weber partook of this opinion, although Muller‡ had already shown the morphological differences of the two in birds, and Rathke§ in snakes. That this holds good of Mammalia was first maintained by Bergmann‖ and the author of this article¶, on the ground of their comparative researches; and it was afterwards reduced to certainty by the observations of Kobelt** on the development of the genitals in the human subject. As Müller and Rathke had previously found, Kobelt showed that, at an early date of embryonic life, tubes and seminal ducts exist simultaneously in all individuals, but that, in the different sexes, only one of these canals attained a complete development.

If the seminal and Fallopian tubes were identical structures, the Weberian theory of the morphological nature of the vesicula prostatica could not possibly be correct; for, in that case, the former of these must constantly open into the upper end of the vesiculæ, or into its two cornua respectively, which is never the case. But now that we know the difference of these two canals, the anatomical arrangement of the vasa deferentia and Weberian organ no longer constitutes an objection against the explanation of the latter as the uterus.

* Opus cit. S. 49.

† Zur Morphologie, &c., S. 47.

‡ Bildungsgeschichte der Genitalien. Bonn, 1830.

§ Entwickelungsgeschichte der Natter, S. 212. Königsberg, 1839.

‖ Op. cit. in Wagner's Handworterbuch.

¶ Zur Anatomie, &c., S. 90.

** Der Nebeneierstock des Weibes. Heidelberg, 1847.

But it is not on this that Meckel chiefly relies. He conspicuously brings forward another argument. He states that, if with Weber we regard the vesicula prostatica as the uterus, and its opening as the os tincæ, we must in consequence consider as the vagina the beginning of the uro-genital sinus, into which open, beside the vesicula, the ejaculatory ducts and the urethra; a view which has often occurred to the author of this article. But, in the female Mammalia, the vagina never receives the urethra. This is always inserted at the outer border of the vagina, where it passes into the short and sinus-like dilatation of the uro-genital canal (*vestibulum, atrium vaginæ*), so that the vagina always lies internally to the aperture of the urethra.

Its relation to the vasa deferentia is exactly similar, as the history of their development proves that they are originally the efferent ducts of the Wolffian bodies. It is true that these latter generally disappear in the female mammal, but here and there some relics of them are left. This is especially the case in the female ruminant and pig, where they are known under the name of Gartner's canals. Here also they open, never into the vagina, but into the ductus uro-genitalis, together with the urethra. So that in all cases, after the points of opening of the urethra and vasa deferentia, the vagina comes next interiorly. And in the male mammalian the Weberian organ has this situation: it is therefore, concludes Meckel, the vagina, and not the uterus.

While I allow the correctness of the facts brought forward by Meckel, and while,— against my own earlier opinion,— I have some scruples as to the unconditional accuracy of Weber's explanation, yet I cannot approve of Meckel's conclusion. The form of the Weberian organ, the bifurcation at its upper end, which occurs in so many instances, even its being imbedded in a transverse fold of peritoneum (corresponding to the broad ligaments of the uterus) remind one too closely of the female uterus to admit of the analogy being mistaken.

Now, in order to reconcile this circumstance with the facts brought forward by Meckel, there remains but two expedients; either to suppose a complete deficiency of the vagina in the male mammal (in which case the explanation of Weber would be preserved entire), or to set forth the Weberian organ as the morphological equivalent of the vagina and uterus together.

The latter of these two acceptations, which I have already defended against Meckel in another place*, finds its full confirmation in the observations on its normal and abnormal development. On these grounds it may be advisable to review them briefly in this place.

From the exposition which Rathke † has given us of the development of the vagina and uterus, it becomes evident that these two structures at first present the appearance of a common or inseparable tube, the genital canal, which is only afterwards divided into an upper and under section by a different development of its coats, being connected with a transverse dismemberment. One of these is developed into the vagina; the other forms the uterus. At its first formation the uterus is simple: its cornua only begin later, when the tubes enter its cavity.

Now, if this genital canal sustained a check of development prior to the separation of the uterus and vagina, it would remain as a simple tube, the horns of which would be either not at all or but imperfectly developed: in short, it would be a Weberian organ.

In this way the observations on the normal development of the genitals do not in the least contradict the explanation of the Weberian organ as a genital canal (uterus *plus* vagina). It is true that we can scarcely thence deduce an absolute proof. We find it, however, in the evidence afforded by the pathological history of its development, since we observe that the Weberian organ is there metamorphosed into both of these parts.

I have already mentioned above, that a knowledge of the Weberian organ is of the greatest importance in the study of hermaphrodism — a study which now requires a fundamental revision in connection with the recent observations on the morphology of the genitals — and especially since the numerous * instances of androgyny for the most part depend upon an excessive development of this structure in the male individual, — associated with some other abnormal occurrences in the development of the uro-genital canal and the penis, which appear at the same time, according to the law of coexistence.

I have now a number of such androgyni before me. They are all goats, in whom this deformity of the genitals is proportionately very frequent. The exterior segments of the genitals (uro-genital sinus and penis) are, in different degrees of development, formed after the female type, *i. e.* they are checked in their development to male parts; and so also is the Weberian organ; while instead of ovaries, testicles with epididymes and seminal ducts are present.

In one of these, a new-born animal, the Weberian organ forms a very considerable tubular dependency, which opens by an oval and fissured aperture of about $1\frac{1}{2}$ lines in length, close beneath the two vasa deferentia, in the commencement of the short and wide uro-genital canal. (*Fig.* 882.) From thence the Weberian organ ascends for about two inches as a short and wide cylinder, to split at its extremity into two horns of an inch in length. The left horn is hollow in its whole course, but the right only in its lower half. The

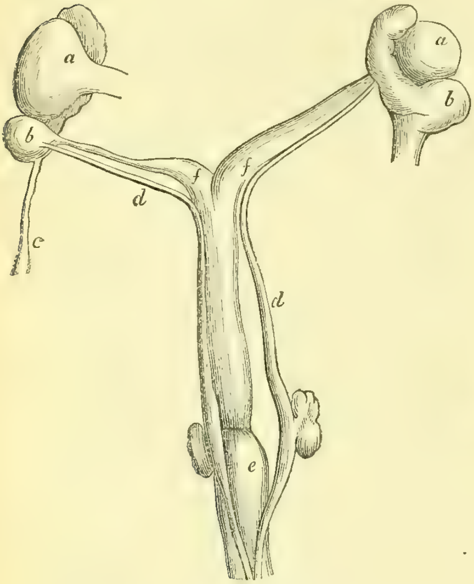
* Gottingische Gelehrte Anzeigen, loc. cit.

† Abhandlungen zur Bildungs- und Entwickelungsgeschichte, Leipzig, 1832, S. 60.

* Another smaller number of androgyni includes female individuals, with excessive development of the Wolffian bodies and their efferent ducts (Epididymis and vasa deferentia). *Vide* Simpson, loc. cit., p. 707.

vasa deferentia course along the anterior surface of the Weberian organ, and are connected thereto by areolar tissue. Subsequently to the splitting they run along the

Fig. 882.



Internal Genitals of a Male hermaphrodite Goat.

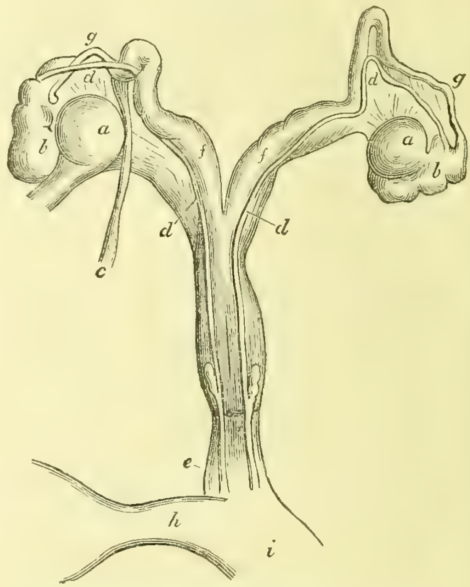
a, a, testicles with epididymis *b, b*; *c,* gubernaculum testis; *d, d,* vasa deferentia with the seminal vesicles; *e,* vagina; *ff,* cornua of the uterus.

lower border of the cornua, between the two lamellæ of the ala magna, but soon become continuous with the canal of the epididymis. The testicles have not descended into the scrotum. They lie at the ends of the cornua, the outer coverings of which pass into the sheath of the epididymis. If the vasa deferentia (which are somewhat thickened at their lower extremities, and, at about six lines from their apertures, possess a pair of seminal vesicles which lie more deeply), be removed from the Weberian organ, it will be seen that the lower end of the latter (*e*) is wider in an extent of nine lines than the segment which lies above it, and is distinguished therefrom by a constriction. By a further examination of the interior at this point, I find a transverse fold by which the two segments are still more separated from each other. Although this fold is not a complete os tincæ, yet it cannot be doubted that the two segments of the Weberian organ, which are limited thereby, are the uterus and vagina; the less so that they possess different developments of the muscular and mucous membranes, which, in appearance and structure, exactly correspond with these membranes in the uterus and vagina of a new-born female goat.

In a second individual I remark a very similar form and development of the Weberian organ: excepting that there is a much more considerable size and capacity, which is due to the adult age at which the animal was killed. But here there is no separation into vagina* and uterus. But, in spite of this, by a comparison with the normal female genitals of an individual of the same age, one will easily be convinced, that the Weberian organ in this instance corresponds to the uterus with the vagina, and not to the former of these only.

But this may best be seen in a third hermaphrodite now lying before me (*fig.* 883.). Here the Weberian organ is so completely separated into uterus and vagina by the development of

Fig. 883.



Internal Genitals of a Male hermaphrodite Goat.

a to *f*, as in *fig.* 883. ; *g, g,* Fallopian tubes; *h,* urethra; *i,* uro-genital canal.

a formal os tincæ, that it might almost be thought, from the simultaneous presence of the Fallopian tubes †, from the very consider-

* The *hermaphrodite* goat figured by Gurlt (Path. Anat. Tab. 22. fig. 3, 4.), and copied by Simpson (loc. cit. p. 300.), exactly resembles this; only the horns of the uterus were here produced for a great length, because the testicles had descended through the inguinal canals into the scrotum.

† The presence of real tubes in the so called Androgyni is very rare, and has perhaps hitherto been observed with certainty only by Mascagni in the bull. (Atti di Siena, vol. vii. p. 201.) What are usually thus called are only the longly produced horns of the uterus. All that lies between the body of the uterus and the Hunterian ligament belongs, to the cornu of the uterus. The tubes always lie, as H. Meckel has pointed out (l. c. S. 43.), on the other side of the Hunterian or round ligament, as is represented in my case by the figure above. At the end of the tubes in this case, there is a small, almost cup-shaped, nodosity at the inner border of the epididymis, which is apparently the imperfectly developed fimbria.

able width of the vaginal orifice, and the almost female uro-genital canal, that we had a true female before us. The testicles (*a a*), which remain in the abdominal cavity, possess a true ala vespertilionis, and also exhibit a more solid parenchyma than usual, although they consist of spermatic gland-canals. Only the epididymis and vas deferens are distinctly male in character. The latter (*d d*) takes the same course as in the instance previously described, except that the lower ends are completely buried in the anterior wall of the body of the uterus and the vagina (like the Gartner's ducts), and the seminal vesicles are much smaller.

In this way we acquire a conviction that the Weberian organ, by a further development, is formed — not into a uterus only, nor yet into a vagina only — but, at least as a rule, into both these structures simultaneously. Hence we need not scruple to regard it as the morphological equivalent of both. *So that the Weberian organ is the male sinus genitalis, which in the female animal undergoes a further development into the vagina and the uterus.*

It is certainly an important guarantee for the correctness of this theory, which had been casually expressed for some time by Bimbaum *, and is now—from a communication to me by letter — shared in by my friend H. Meckel, that it had been applied by E. H. Weber † himself, to the vesicula prostatica of the rabbit. From a comparison with the female organs, he came to the conviction, that it represented the uterus with the vagina; but unfortunately he neglected to extend this view, and in the other Mammalia he regards the vesicula prostatica as only a masculine uterus.

We have mentioned above that the lower part of the Weberian organ is occasionally contrasted with the upper, either by an annular constriction, in man, or by a singular width, as in the horse: or that the contrast may be limited to particular individuals, as in the goat. It is evident that this can only be explained as a transverse severance into uterus and vagina, a condition which certainly is never normally completed in the male animal.

And when, as sometimes happens in the horse, the upper section altogether disappears, we need have no scruples in regarding the lower remaining part as the vagina only. ‡ In such instances the theory of Meckel holds good: a theory which was but too widely applied by its founder.

Hence it may be laid down as a law, that the upper part of the Weberian organ, which corresponds to the uterus, and which also shows such great variations in the development of its horns, is less persistent than the under part of the vagina. Thus the question may arise whether the Weberian organ, when it is devoid of cornua, still possesses an upper or uterine part. In order to decide this with certainty, every such instance would require a careful analysis, assisted by the history of its normal and abnormal development. But as a rule we are justified in supposing that the Weberian organ is, as was stated above, and as is constantly rendered indubitable by the presence of cornua, both vagina and uterus.

I have here, without further discussion, passed over the question, whether a complete absence of the vagina may not obtain in the male mammalia; a supposition which is required by the unconditional reception of Weber's theory. And this has been done because an assumption of this kind only leads to doubtful morphological hypotheses; the necessity of which seems very inconceivable after the positive results we have already obtained. Wherever the female individual possesses a vagina the Weberian organ is, at least in part, vagina also; even where, as in the beaver, the exterior appearances speak by no means strongly in its favour.

But it is certainly otherwise in the case of those Mammalia whose females lack the vagina. Here I do not so much refer to the monotremata, who, in the development of their genitals, approach much more closely to the birds than to the other Mammalia, and perhaps are devoid of a proper uterus: but rather to the elephant, in the female of which, as Mayer has lately shown *, the orifice of the urethra is only separated by a very small fold from the external orifice of the uterus, and the vagina is absent. The whole genital canal is here metamorphosed into uterus. In like manner the Weberian organ of the young male certainly corresponds to the uterus solely. In any case, such instances constitute but rare exceptions, and do not affect the general interpretation of the Weberian organ.

After all that we have now learnt concerning the morphological import of the Weberian organ, it is scarcely necessary to state, that it, — or rather the embryonic part out of which it is developed in the male animal, — is present in all mammalia up to a certain period of fœtal life. Where it is afterwards absent it must be attributed to a retrograde process of development; which to some extent appears to occur very early, as in the sheep. The date and degree of this retrogression is shewn by the anatomical development of the Weberian organ. In some instances it preserves both its embryonal form and size; in others it continues to increase even after birth, as was especially mentioned of the rabbit.

I recur once more to this animal, because it, with its congeners, is not only conspicuous on account of the described connection be-

* Beschreibung und Kritik einer eigenthumliche Bildungshemmung. Giessen, 1848, S. 15.

† Zusätze, &c., S. 8.

‡ In some pathological instances a vagina exists without an uterus; as was detailed by Ricco (Cenno Stor. su di un neutro uomo), and quoted by Simpson (l. c. p. 703.).

* Beitrage zur Anatomie der Elephanten; in den Nov. Act. Leopold. t. xxii. P. II. S. 38.

tween the Weberian organ and the vasa deferentia, but also on account of its seeming to constitute an exception to the alleged morphological law that the efferent ducts of the Wolffian glands never open into the vagina, but always into the point of its transition into the uro-genital canal. According to my observations in the embryo of the rabbit, even here the ordinary relation is originally present: the Weberian organ opens close behind the vasa deferentia into the uro-genital canal. But very soon a transverse fold arises behind the points of opening of the seminal ducts, and by its continual enlargement, even after birth, it as constantly protrudes these openings outwards into the neck of the Weberian organ. Even in the fully developed condition this fold may be recognised in the anterior swollen margin of the opening of the Weberian organ.

Addendum.—A considerable period having elapsed since the MS. of the preceding article was placed in the Editor's hands, I have availed myself, during that time, of many opportunities both of confirming and extending my observations on the phenomena connected with the Weberian corpuscle. My esteemed friend and colleague, the eminent embryologist, C. H. Bischoff, has, with great liberality, handed over to me a large number of rare preparations, from the collection of the Giessen University, for comparative examination.

From another source also an important addition to the knowledge of this organ has been afforded us; and this I hail with the greater pleasure, as it shows how great an interest attaches itself to this subject in other countries. The treatise to which I allude is the Inaugural Dissertation by Wahlgren, published at Lund.*

I therefore now find myself in a position to fill up many deficiencies in the foregoing paper. For this purpose I prefer the form of a supplement, and hope that the reader will excuse whatever degree of inconvenience attaches itself to it, on account of the circumstances under which a foreign contributor is situated.

Quadrumana.—I formerly conjectured that the true Apes, without exception, possessed the Weberian organ (p. 1416.); in confirmation of this, I can now add, that it occurs both in the species mentioned (*loc. cit.*), and in *Pithecus troglodytes* and *Cynocephalus porcarius*. Wahlgren observed it likewise in an undescribed species of Ape. It appears, however, not to occur throughout the group in an equal manner. In the *Lemur albifrons*, I observed on the colliculus seminalis a fine longitudinal fissure, between the apertures of the seminal ducts (a fine capillary canal entered it a short distance—but this may have been made in mounting the preparation): in *Stenops tardigradus* I have, however, convinced myself of the absence of the organ.

Feræ.—Wahlgren describes the Weberian corpuscle in *Felis lynx* as an oval cavity, three lines in length, and opening by a fissure-like aperture into the uro-genital canal on the middle of the verumontanum. In the Brown Bear it is similar, but much larger (5‴), pear-shaped, and with a considerable aperture. *Nasua fusca*, also, according to Wahlgren, possesses a similar gland. In the *Otter*, I have now observed this organ in two specimens. It is disposed as the foregoing, and; as was conjectured, has a considerable central cavity, with a small aperture. The cornua are solid ligamentous cords.

Marsupialia.—The marsupial animals appear to be very generally destitute of this organ. In *Halmaturus giganteus*, *Phascolomys wombatus*, and *Sarcophilus ursinus*, I found no more traces of it than previously in *Didelphys virginiana*. Wahlgren also found it absent in *Halmaturus giganteus*.

Rodentia.—The remarkable structure of this organ in Rabbits and Hares might well belong to the whole group of the *Leporinæ*. In *Lepus borealis* it is the least, *cæteris paribus*, according to Wahlgren. Yet here it attains even the colossal size of three inches, with a proportionate breadth (up to 1″ 10‴). With the *Palmipedia*, on the contrary, it is otherwise. Distinct as it is in the *Beaver* (p. 1418.), it is but little developed in the nearly related *Myopotamus coypus*, in which Wahlgren found a mere rudiment, consisting of two thread-like cords. The two agreed in their position with the Weberian corpuscle of the *beaver*, and enclose a small cavity, with an opening on the colliculus seminalis. With regard to *Sciurus*, Wahlgren confirmed the absence of the organ: nor was it observed in *Lemnus*. *Hystrix cristata* and *Hydrochærus capybara* are likewise without it, according to my own observations. In the last, however, as in the closely allied *Agouti* and *Cavia*, the two seminal ducts have a common, cavernous, wide aperture.

Edentata.—Besides the *Bradypus tridactylus*, I have lately examined *Cholœpus didactylus*, also *Dasypus octosus*, and *Ornithorhyncus paradoxus*. In none of these is the organ present. Wahlgren also states the same of *Ornithorhyncus*.

Ruminantia.—The Weberian organ appears to be generally present in the *Cervina*. That of the *deer* is above described (p. 1420.). It is far more considerable in the *Hart* and the *Reindeer*, where it ascends between the seminal ducts in the form of a cylinder, about two inches long, which in the former is distinctly bi-cleft at the extremity. There is an internal cavity, which in the *Hart* is continued into the cornua, and opens on the verumontanum. In the Goat there are numerous individual varieties in the development of this organ, as I have before mentioned (p. 1420.). In many instances it is altogether wanting, as I have now convinced myself. In one case I

* Bidrag till Generations-Organernas Anatomi och Physiologi hos Menniskan och Daggdjuren, 1849. Translated by Peters into German, in J. Müller's Archiv für Anatomie und Physiologie, 1849, S. 686., *et seq.*

saw it in the form of a single longish body (3‴), between the vasa deferentia; in another it continued upwards as a long solid cord, which adhered by its bifurcate extremity to the seminal ducts. In both cases it had a distinct opening. The wide differences in the development of the organ above mentioned, are of rare occurrence.

As regards the *Sheep*, the absence of the Weberian corpuscle in the perfect form has been already stated. According to Wahlgren, however, such is the case (as in the Goat) in isolated individuals only; whilst in others, on the contrary, a small purse-shaped body represents this organ.

Wahlgren describes this organ as occurring in the *Bullock* in the form of a flask-shaped sac, 6-7‴ long. That here also many varieties occur (as pointed out by my observations), is evident, for in another (castrated) animal it was present as a short uniform canal.

Cetacea.—In a young specimen of *Delphinus delphis* (so labelled), I now find, *as already stated in regard to other species*, two thick, cleft-shaped, closely approximate pseudo-representations of this organ. The examination of the *Halicore dugong* was of particular interest to me. This animal, belonging to the group of herbivorous whales, possesses a Weberian organ, having a small roundish (and bordered) opening on the colliculus seminalis. Its form and size cannot be accurately determined on account of the condition of the preparation; it appears, however, to be about an inch in length, and in shape like a wide longish bottle.

A peculiar structure here distinguishes the commencing portion of the uro-genital canal. Instead of exhibiting a direct continuation of the urethra, it begins with a peculiarly wide cavity, which is bent outwards like the belly of a retort, and receives the urethra (under which the large colliculus seminalis rises prominently) on its hinder wall. I know of only one male mammal that presents a similar structure, viz. the Hedgehog; nor in this case is the disposition of parts so remarkable. When, therefore, Wahlgren asserts that this cavity at the commencement of the uro-genital canal in the Hedgehog is the Weberian organ, he is in error; as is proved by the co-existence of both of these peculiarities of structure in the *Dugong*.

In reference to the *morphological* signification of the organ in question, Wahlgren completely agrees with me. He also views it as the representation of the whole female sinus, that is, the uterus and vagina taken together.* We must not forget that, as we have already observed, the latter of these two parts finds a complete and general representation in this organ. This especially applies to the simple form of this organ, when it occurs as a mere oval body without upward continuations of the cornua; and among others, to the human utriculus, which, on that account, in the case of an abnormal enlargement, becomes merely a vagina. Steglehner has already remarked* on this subject, that the so-called uterus cystodes of Ackermann's well-known hermaphrodite case (Art. HERMAPHRODITISM, Vol. II. p. 709.), answered, not to the uterus, but the vagina. I have been led to the same results by the examination of a great number of human hypospadiacs and hermaphrodites. A true uterus, as in the single case of Mayer†, is indeed only seldom found on such a vagina. The vasa deferentia pass constantly on the anterior wall of this vagina, and open near it in the uro-genital canal, like Gartner's canals in the *Ruminantia*. They are never connected with the vagina itself, as Hyrtl has observed.

(*Rud. Leuckart.*)

* Still more recently, on the contrary, Van Deen affirms (Zeitschrift für wissenschaftl. Zoologie v. Siebold und Kölliker, 1849, S. 268.), also Betz (Müller's Archiv, 1850, S. 65.), that the Weberian organ is exclusively the "uterus masculinus." We do not here again enter into a critique of this view, and must refer our readers to our former remarks. We must mention, however, that the first of these articles contains very numerous errors, and many odd hypotheses.

VESICULÆ SEMINALES. — These are a pair of sacculated organs, peculiar to the male, situated behind the bladder, between it and the rectum. In man they appear, externally, as multilocular cysts about two inches in length and three quarters of an inch in their greatest breadth. Their shape is fusiform; their larger ends diverging from one another, and their smaller ends converging so as almost to meet. These smaller ends are surrounded by the prostate, and are directed slantingly forwards, as well as downwards and inwards. Along their inner sides pass the vasa deferentia, with which they join, by a narrow outlet, at the base of the prostate.

The vesiculæ are invested by a fascia derived from the prostate, which can be removed by careful dissection, and then they are found to consist of a blind tube of about the calibre of a small goose quill doubled upon itself again and again, all the gyrations being held together by cellular tissue, so as to give the appearance of fusiform multilocular sacs. A little careful maceration will enable the anatomist to unravel these gyrations, when each vesicula will sometimes be found to be one simple cæcal tube about six or eight inches long, or, more frequently, there will be three or four cæcal diverticular appendages to the main tube, in which case the greatest length (that of the central main tube) will be very much less. This tube has a very much smaller calibre for a short distance from its junction with the vas deferens than elsewhere. The narrow portion is straight, and is commonly called the duct of the vesiculæ seminales.

These vesicles are found to contain a synovia-like brownish mucus, the nature of

* De Hermaphroditorum Naturâ. Bambergæ, 1817, p. 97.

† Vol. II. Art. HERMAPHRODITISM, fig. 303.

which we shall have to inquire into presently, when we treat of their function.

The fascia that invests the mass of gyrations, like a fusiform bag, contains a great proportion of involuntary muscular fibre, and there is also a large admixture of involuntary fibre in the proper parietes of the tube. It is, of course, lined throughout with a mucous surface, which has a faint reticular marking, like that of the stomach in some animals, and is evidently glandular, or secreting.

Comparative Anatomy.—Some considerable difficulty has been experienced by comparative anatomists in identifying the vesiculæ seminales in different animals. This has given rise to much discrepancy as to their existence, or non-existence, in certain species. In the *Ruminantia*, for instance, the prostate assumes the very singular form of two organs, each having a large central cavity opening into the urethra by a single duct; and these organs, very naturally, have been regarded by some as vesiculæ seminales. Who, indeed, can undertake to say, with certainty, that they are not? It is far from improbable that they are both the one and the other—prostate and vesicula at once.

There are two very distinct kinds of comparative anatomical identity—*functional identity* and *homological identity*. Instances are very numerous of homologically identical parts being very diverse in function; the function of the (homological) hand, for instance, is to seize with in man, to walk with in the horse, to fly with in the bat, and to swim with in the whale. And there are not wanting many instances of parts functionally identical, and homologically diverse; a striking instance of which is furnished by the urinary bladder in Mammalia, compared with the reservoir of urine sometimes met with in Ovipara. In the case now before us, the function is in question, and the homology by no means *prononcé*; no wonder then that identification should be difficult and uncertain. We proceed, however, to notice the various forms of certain sacs met with in brute animals, posited in close relation to the vasa deferentia, and impressing one somehow, perhaps homologically, with a notion that they are identical with the human vesiculæ seminales.

Such vesiculæ are exclusively confined to the *placental* division of the *Mammalia*. They are not met with in the *Marsupialia* nor *Monotremata*, nor in the other vertebrate classes, — *Aves*, *Reptilia*, nor *Pisces*. In some of these, *Aves* for instance, there are undoubted reservoirs of semen, formed by dilatations of the vasa deferentia; these, however, are manifestly not the organs in question.

Reservoirs of semen are also met with in some *Invertebrata*, but since, as I have elsewhere noticed (Art. Symmetry, Vol. IV., p. 850.), homological identity of parts can in no instance be established in animals belonging to different sub-kingdoms, the only identity being in all cases merely that of function, these have no title to be described in an article on the vesiculæ seminales, from which by function they are, as will be seen hereafter, for certain diverse.

They are indubitably present in all the *Quadrumana*, the *Cheiroptera*, and the *Insectivora*. They are wanting in the *Carnivora*. Present in the *Rodentia*, and *Pachydermata*, and in the *Manatee*. In the other *Cetacea* they are absent. In the *Ruminantia*, the questionable organs, mentioned above as hollow prostates, occur.

In the higher *Quadrumana* they much resemble those of man; and their ducts join the vasa deferentia much in the same manner as in the human subject. In most of the lower monkeys they have not the convoluted form, but occur as simple sacs, and the outlets, at the side of the verumontanum, alone are common to their ducts and the vasa deferentia. In *Galeopithecus* they are remarkably small.

In the *hedgehog* their size is enormous—twice that of the vesiculæ in man—and they have a very interesting form. They consist each of a small central duct, from which ramify very numerous convoluted cæca of much greater calibre. The central duct terminates on the verumontanum, near the vas deferens.

In the *Rodentia* they are, mostly, very large. In the *rabbit* and *hare* they are, apparently, fused together, and form a single mesial sac, the upper end of which is somewhat square, thick and glandular. This sac opens by a mesial orifice, which receives the vasa deferentia, upon the verumontanum. It is, however, very improbable that this really (homologically) represents the vesiculæ seminales; its mesial position, between the vasa deferentia, is essentially different from that of the vesiculæ, which is always external to those ducts. It is most probably the utriculus prostaticus. In the other Rodents they are double;—long, simple, and bi-fusiform in the *guinea pig*; serrated in the *rat*; having small ramifications in the *agonti*; and convoluted in the *beaver*. In the *squirrel* they consist of a small tube with glandular parietes, and much convoluted. In the *Alpine marmot* they are but slightly developed, very convoluted, and have glandular parietes. In all these their outlets are quite distinct from, though near to, those of the vasa deferentia.

In the *Pachydermata* they assume very various forms. In the genus *Equus* they resemble two small urinary bladders, and have two distinct muscular coats. They are thicker at their fundus than elsewhere; the thickening consisting of a glandular substance. The orifice of their ducts is in common with those of the vasa deferentia. There is also, in this genus, a third vesicular organ, situated mesially between the vasa deferentia, of a long cylindical form, with a rounded fundus, and secreting a substance of the consistence and colour of honey. This is, undoubtedly, the homologue of the utriculus prostaticus. In the *Hyrax* they are very large and convoluted. In the *Rhinoceros* they consist of two large irregular sacs, whose excretory ducts join the vasa deferentia. They are very large in the *elephant*, of an oval figure, with a constriction at their upper end. Their internal surface is divided by irregular columns and grooves, more marked in their upper part, and deficient at the lower. On their outer and anterior aspect is a peculiar muscle, arising from their neck and middle portion, and spreading out over their upper part, which can contract their cavity and expel their contents. Their ducts join the vasa deferentia beneath their ampullated portion noticed below. In the *boar* they each consist of a great number of lobes and lobules arranged around, and communicating with, a small central canal, which opens on the verumontanum, near the vas deferens.

It may not be out of place here to mention several *remarkable peculiarities in the structure of the vasa deferentia*, when they arrive at the back of the bladder, in several animals. In man this part of them is dilated and sinuous, and generally contains a fluid very similar to that found in the vesiculæ. In the *horse* this part of the ducts is extremely thickened by the occurrence of numerous glandular cellules in its walls. These cellules contain a thick mucus. Much the same condition is met with in the *bull*. In the *elephant* each vas deferens, when it arrives at this part, enlarges into a very large cavity, which it is evident may readily, and no doubt does really, fulfil the function indicated by the words vesiculæ seminales.

Function. — With regard to the function of these organs, I am able to come to little more than a confimation of the negative conclusion of Hunter, that *they are not reservoirs of semen*. Hunter's positive conclusion that *they form part of the generative apparatus*, is pretty clearly proved. I proceed to offer the evidence from which these two conclusions are arrived at.

1st. *They are not reservoirs of semen*. That they were receptacles into which the semen might regurgitate and be stored up ready for emission, was doubtless suggested by their connection with the vasa deferentia in the human subject, so like the relation of the gall bladder to the hepatic duct. A very obvious objection to this is that, as we have seen, the same relation does not occur in the majority of animals; but the difficulty of proving the identity of the sacs called vesiculæ in other animals, diminishes very much the force of this objection; and even if a homological identity were proved, still numerous caveats warn us not therefrom to infer their functional identity. It is moreover extremely easy to conceive the possibility of the regurgitation of semen into the vesiculæ, where the two ducts have an outlet, though merely an outlet, in common. (In such cases they join just in the act, so to speak, of debouching.) And it is far from impossible to conceive the regurgitation of semen even when the outlets are distinct, especially in some instances. In the guinea-pig, for example, the outlets of the vasa deferentia, vesiculæ seminales, and prostatic ducts, are surrounded by — occur in the bottom of — a little spout, of about a line in diameter, which projects about half a line into the urethra, slanting towards the outlet. Another objection to their being reservoirs of semen is that the fluid found in them is extremely different from that found in the vasa deferentia, as observed by Hunter, in colour, consistence, and smell; but that they should secrete a mucus of their own, is only parallel with what we know to be the case in the gall bladder; and that admixture with this mucus should considerably alter the character of the semen, is extremely probable. To a microscopic examination of the contents of the vesiculæ, we naturally look for a solution of this question, now that we know the extremely characteristic microscopic appearance of semen — *Are spermatozoa found in it?*

Müller says "That the vesiculæ seminales are really receptacles of semen, is beyond a doubt, since spermatic animalcules have been discovered in their contents in the human subject after death." * To the fact, that spermatozoa are occasionally found in the contents of the vesiculæ, I can add my testimony; but I am compelled by other facts to dissent from the conclusion at which Müller arrives. To infer that the proper function of the vesiculæ is to serve as reservoirs of semen, because spermatozoa "have been" found in them after death, is a *non sequitur*. Spermatozoa may often be found in the urethra, and I have found them in the urinary bladder. These restless little entities often wriggle themselves into organs where their presence is far from usual or normal. Even after death they may be forced into the vesiculæ by the violence unavoidable in removing the parts for examination. The question is, are they *usually* found in the contents of the vesiculæ, and that *in large numbers?* To answer this question I thankfully avail myself of the more extensive observations of my friend, Mr. J. Quekett, who carefully examined the subject some years ago. He tells me that the presence of spermatozoa in the human vesiculæ is not very frequent, even when the sacs are very distended by their contents; and that when they are present, it is in sparing numbers — in fact, as a few stray ones. This accords perfectly with the results of my own researches.

When I find the vesiculæ seminales full to distension with a mucous fluid, and discover, by a microscopic examination, only a few solitary spermatozoa in it, and when I compare this with the crowds of spermatozoa seen in the fluid squeezed from the vas deferens, I cannot believe, even allowing a reasonably broad margin for dilution with mucus, that I am examining stored semen. In the lower animals I have never observed a single spermatozoon in the contents of their vesiculæ seminales, although I have carefully examined it taken from individuals that had been purposely subjected to prolonged sexual excitement ungratified. My observations, however, have been entirely confined to those brute animals the ducts of whose vesiculæ do not join the vasa

* Physiology. Translation by Baly, p. 8181.

deferentia, which, as may be seen by reference to the comparative anatomy cited above, is the case with all the lower animals readily procurable, alive, and in functional activity, in this country. The best evidence that comparative anatomy affords on the subject is, that, in the elephant, vesiculæ seminales, joining the vas deferens just as in man, coexist with unmistakeable seminal reservoirs. If the vesiculæ were merely receptacles of semen their presence here would be quite supererogatory, and contrary to Nature's usual fashion. It adds to the signification of this fact, that the junction of the ducts occurs below the enormous ampulla, that is, between it and the urethra; so that the ampulla must be filled before any semen could be regurgitated into the vesiculæ.

Still, as spermatozoa are occasionally found in the human vesiculæ seminales, microscopic evidence, of itself, is not able to give us that complete negation of the old and widely spread view of the functions of the vesiculæ which I have ventured upon above. And here the acute observations, unaided by the microscope, of the immortal Hunter, of themselves sufficient to prove this negation almost to a certainty, afford such an accession of proof as cannot fail to be convincing. He examined the vesiculæ in several subjects in which one testicle had been extirpated a long time before death, and he found in every case that the *vesicula of the castrated side was as full as that of the other.* One of the cases examined by him was a married man in whom he had extirpated the left testicle a year before his death. "On examining the body, the vesiculæ were both found nearly full, more especially that on the left side, which might have been accidental." To remark that the vesicula of the castrated side was fuller than the other seems to be proving too much (he observed the same in one other case); but the rest of his cases show clearly that this was, as he says, accidental. These invaluable observations of Hunter, together with his comparison of the thick brownish mucus found in the vesiculæ, with the extremely different, milky, slightly viscid semen in the vas deferens of the same subject, and the contrast observable in the two fluids by aid of the microscope, — a few scattered spermatozoa or none at all in the one, crowded myriads in the other, — lead irresistibly to the conclusion that the vesiculæ seminales are not reservoirs of semen.

2dly, *They form part of the generative apparatus.* This is pretty clearly proved by Hunter, by observations made on those animals that have periods of rut or sexual excitement alternating with periods of sexual quiescence or impotency, such as the stag, the mole, and the land-mouse. In these animals the vesiculæ seminales, in common with the testicles, prostate gland, &c., are exceedingly small during the period of impotence, and enlarge enormously and rapidly for the season of rut. In the mole they are hardly discernible in winter, but become enormously large in spring. Conclusive, however, as this proof appears, *primâ facie*, to be, it is somewhat weakened by the fact that much the same thing happens, in various animals, to other parts which would scarcely be enumerated as belonging to the generative apparatus, such as the horns of the stag, the comb of the cock, &c. Yet, adding to the fact of this periodic enlargement and diminution the anatomical position and connections of the vesiculæ, together with their absence in the female, there is constituted a very satisfactory proof that they form part of the male generative apparatus.

These conclusions, however, merely bring us two steps nearer to a definite knowledge of the exact office fulfilled by the organs in question. I now proceed to adduce such other observations as I have been able to make, or have found upon record, as may aid in forming an hypothesis as to their positive function, or may appear interesting.

The mucus found in the vesiculæ is, as will readily be admitted from what has been said above, undoubtedly secreted by their glandular parietes. This is still better proved by a case of Hunter's, where, as a congenital defect, they had no outlet (nor inlet), and yet were full of mucus. This case shows also that they have the power of re-absorbing their secretion, or at least renders it highly probable. A mucus in all respects similar is usually found in the part of the vas deferens immediately contiguous to the junction of the duct of the vesiculæ. This is very probably secreted by the walls of this part of the vas — in the horse there is no doubt of it. The mucus of the vesiculæ is very thick and viscid in all animals, but more so in some than in others. I have examined it carefully in the guinea-pig, in which animal it is remarkably thick; but there is a difference, in this respect, between that which is near the outlet and that which is at the fundus, it being thickest in the former position and gradually thinner towards the latter. It is transparent, granular, and has a faint opaline blue colour. I found that it rapidly solidified upon being squeezed out of the vesiculæ, and that too even when not exposed to the air and when not subjected to any remarkable diminution of temperature, when lying, in fact, in the urethra of the animal just killed. The mucus contained in the vesiculæ also solidified more though slowly — that in the fundus most slowly, and the rest in gradual progression up to that near the outlet. In opening the abdomen of a guinea-pig, it is almost impossible to avoid compressing the vesiculæ, and probably from this cause a considerable quantity of the mucus is forced into the urethra, where I always found it forming a solid mass as hard and elastic as the cartilage of a ray-fish, and moulded to the shape of the urethra: this within a few minutes after the death of the animal. Now, this is just the contrary to what, according to Hunter, is the case with emitted semen, which becomes more and more fluid under exposure. I was, however, highly interested to observe that if the vasa deferentia and vesiculæ be compressed at the same moment, so that the mucus and semen shall mix in the act of escaping into the urethra, and they do mix in a remarkably perfect manner in the little spout-like verumontanum of the guinea-pig, then the immediate solidification of the mucus does not occur. Whether this curious effect of their mixing is due to the mechanical whipping of the spermatozoa or to a specific solvent power for mucus in the semen, must remain undetermined at present.

The degree of liquefaction produced seems to be much greater than what would be due to simple admixture, that is to say, it is much greater than would be produced by adding a drop of water equally small to a mass of gum, for instance, equally thick and equally large. This throws fresh light on some observations of Hunter's, made upon guinea-pigs. He killed a male (which, by the way, he had castrated on one side six months before), immediately after it had copulated, and he found the vesiculæ of both sides full. He also killed a female immediately after she had received the male and "examined with attention what was contained in the vagina and uterus; in neither," he remarks, "could I find any of the mucus of the vesiculæ, which from its firmness must have been easily detected." He regards these facts as proof that the contents of the vesiculæ are not emitted in copulation; but that part of the proof based on the non-detection of thick mucus in the vagina and uterus is, of course, much weakened by the fact of the liquefying property of the semen. The other part of his proof, derived from the fullness of the vesiculæ immediately after coitus, is, perhaps, answered by the following observations. The vesiculæ are never found empty—except when they are diminished during the periodic rut in certain animals — in fact they seem to all appearance equally full at all times, but here no doubt appearances are deceitful; they contract and expand according to the volume of their contents, so that they are never flaccid, and always appear to be as full as they can be. I have observed them exceedingly full and large in an animal just killed, and have watched them contracting under the stimulus of exposure to cold air, and when nearly the whole of their contents have been expelled by the contraction, they have still *appeared* to be quite full,—I should have considered them to be so if I had not actually seen them expel their contents. It is evident that the whole contents of the vesiculæ are not emitted in one copulation, but there is strong reason to believe that a part is.

The semen which can be squeezed from the vas deferens is milk white and has very little if any viscosity. Now Hunter describing emitted semen says, "the semen first discharged from the living body is of a bluish white colour, in consistence like cream, and similar to what is found in the vasa deferentia after death (?); while that which follows is somewhat like the common mucus of the nose but less viscid. The semen becomes more fluid upon exposure to the air, particularly that first thrown out." Here then is a mucus, which very probably is from the vesiculæ. I am convinced that it does not exist in the semen of the vas deferens.

The mucus of the vesiculæ, examined in the guinea-pig, is not soluble in water. The urine of the animal seems to solidify it in an extreme degree, for if a little of it gets into the urinary bladder it becomes as hard as spermaceti. Boiled in water it shrivels up slightly, but is not in the least degree dissolved. I dissolved it by repeated boiling in solution of potash, by which means I procured a perfectly limpid, colourless solution. This yielded no precipitate on the addition of acetic acid. In neither of these respects, therefore, does it differ much from the ordinary varieties of mucus. (See Art. Mucus, Vol. III. p. 482.) Submitted to microscopic examination, I have found it to consist of a very sparing quantity of fluid, in which are suspended little conglomerated masses of transparent solid, just visible by the naked eye. The majority of these are of a pretty uniform volume, and appear, when magnified fifty diameters, about the size of duck shot; there are, however, much larger ones and much smaller. Their general contour, whether they be large or small, is spherical, and they have a nodulated, mulberry-like surface, as if composed of smaller balls. The smaller component balls have also an irregular, granular surface, and neither they nor the large conglomerate spheres show any distinct trace of being enclosed in a cell-membrane. I have, however, sometimes observed numerous nucleated cells in a portion taken from the fundus of the organ. But often I have sought for these in vain. I have never found them when the vesiculæ have been exceedingly full and distended, in which circumstances, most probably, secretion would be arrested, and perhaps even absorption going on. These cells are about the size of the smaller (component) spheres. I am tempted by these observations to conclude that the cells I met with were the secreting epithelia of the vesiculæ, and that becoming filled with inspissated mucus (?) they conglomerate themselves into larger spheres. I found it convenient in making these examinations sometimes to add a little white of egg, which produces no alteration in the appearances beyond a greater isolation of the spheres. When water is added, the outlines of the spheres become much more distinct, showing a greater difference of refraction of light, and there become perceptible very numerous insoluble globules, which have a great tendency to coalesce, and appear very much like oil; their refractive power is, however, less, and there are other reasons for doubting that they are really globules of oil. When semen is mixed with this secretion of the vesiculæ, the spheres are still visible, and the spermatozoa are seen disporting in the fluid between them. No solution of them is clearly detectable. This, however, it should be observed, is when the mixture is exposed to cold, &c. in examination;

it might be different when it is lodged in the uterus or vagina of the female.

For reasons given hereafter, I am led to believe that the quantity of actual semen from the testicles emitted at each copulation, is most probably very small, perhaps only three or four drops, at all events not more than the vas deferens is capable of containing. Such an extremely small quantity would be lost in the capacious canal of the urethra, or still more in the enormously capacious canal of the vagina, in the uterus, and in the Fallopian tubes. Some dilution, some addition to the volume, seems necessary in order to obtain an efficient injection of the life-giving fluid. And the quantity actually emitted by a man amounts, by all accounts, to two or three drachms. There has been an addition somewhere. The prostate has doubtless contributed its share, the tiny glands of Cowper theirs, the urethra has given its mite of mucus, more mucus is awaiting in the vagina, and I believe that the vesiculæ are not behind in adding a portion of their hoard of ready-formed mucus to the general stock. The spermatozoa huddled and crowded in countless millions in the vas deferens are now able to disport themselves at ease in the congenial medium; and the number contained in a few drops of pure semen would be sufficient to people abundantly several drachms of fluid.

I am induced by these considerations to form the hypothesis that the office of the vesiculæ is to secrete, and keep in store, a mucus of such a nature as is congenial to spermatozoa; which answers the simple purpose of diluting the semen secreted in sparing quantities by the testicles. By diluting I mean merely increasing the volume, not liquefying; for the mixed fluid is more viscid than pure semen. This hypothesis I would, however, have regarded as only provisional until more satisfactory evidence is obtained. It is the only one which the facts at present known warrant. One is much inclined to doubt that so singular an organ as the vesiculæ is devoted to so simple a purpose. The prostate is generally believed to perform an exactly similar office; and one is still more loth to believe that two organs so different in appearance as the prostate and vesiculæ have an identical function. But as I have advanced this hypothesis I proceed to defend it on these and other points.

That organs, having the air of being very important, are sometimes engaged in performing a very simple and subordinate function, is instanced by the salivary glands, which afford also an example of several distinct organs fulfilling exactly the same purpose:—the parotid, the submaxillary, the sublingual, and the numerous little buccal glands, all engaged in secreting a moistening and diluting fluid, which is not indispensably necessary. All these salivary glands are, however, very much alike in appearance and structure, whilst the vesiculæ seminales do not in any way resemble the prostate. In reference to the human subject this remark is true, but not as regards many brute animals. In the guinea-pig the prostate is composed of numerous ramified cæca, but loosely bound together, and not very small in calibre, and the vesiculæ really appear as though they were merely a couple of the prostatic cæca gigantically developed. The secretion of these prostatic cœca is also exactly similar to that of the vesiculæ. Objections to the identity of the functions of two organs, based on the difference of their appearance, are completely answered by observing the enormous difference of appearance of the liver, for example, in vertebrata, compared with the liver of a crab or lobster; or, what is more similar to the case under consideration, the large and remarkable gland that secretes the egg-shell in the ray-fish, compared with the part which secretes the egg-shell in birds, which is nothing more than just a peculiar villosity of one portion of the oviduct. It is not now my task to enquire into the function of the prostate, I am merely combatting an objection that may be raised to the hypothesis which I am advocating.

The question very naturally suggests itself, how is it that the vesiculæ are absent in several animals of the mammalian class? In birds and reptiles there is no urethra, no vagina, no uterus for the semen to be lost in: the orifices of the vasa deferentia are brought into immediate apposition with those of the oviducts in the act of copulation; but in the carnivora, where the vesiculæ are indubitably absent, the semen has to find its way, meandering through all those labyrinths; and in the kangaroo, the wombat, &c., the males of which have no vesiculæ, the vaginæ of the females are remarkably long, double, and singularly crooked (see Vol. III., *fig.* 138,). The answer to this is, the males of these animals possess a great number of glands (loc. cit. *figs.* 135, 136. and Vol. IV. *fig.* 875.), pouring their secretion into the urethra, which secretion, not improbably, serves the same purpose of dilution.

With respect to the difference of the contents of the vesiculæ in different animals, so obvious, for instance, in respect of their consistence or viscosity, it should be remembered that we have evidence of a specific relation between the spermatozoa of a given species and the medium in which they are destined to float after their exit from the spermatic apparatus. I allude to the fact noticed in the article Semen (Vol. IV. p. 504.), that the spermatozoa of a marine non-copulating species continue their movements in sea water, but become instantly motionless and dead when treated with fresh water, which has no injurious effect on the spermatozoa of freshwater species. This may, perhaps, also throw light upon the function of other accessory seminal glands. Every copulating species is probably able to supply, from one or several glands, a medium congenial to its own spermatozoa.

There is then no special reservoir for semen in the human subject, nor in the great majority of mammalian animals. What then becomes of the secretion of the testicles when it is not used? Another question also requires to be answered. The semen, as will be seen by referring to Art. SEMEN, seems to be a highly elaborated secretion. There is none amongst the various secretions of the body that seems to require so much time for its elaboration. Not only have cells to be formed and thrown off, as in the case of other secretions, but, after they are liberated in the tubules of the testis, nuclei have to divide, nucleoli to multiply, and each division of the nucleoli to become, through a gradual adolescence, an adult spermatozoon. This surely requires time; how can such a fluid be improvised at any moment when copulation may take place?

To the first of these questions I would answer, the testicles do not go on continually secreting, but stop when there is no occasion for their action; as I have convinced myself by observing, that the vas deferens is generally found empty in men who have been long removed from the society of women. Hunter arrives at the conclusion, that the vas deferens and testicles can and do reabsorb the unused semen, and that conclusion it is impossible to avoid, because there are many instances on record of the vasa deferentia being imperforate in a subject whose testicles were in full functional activity. But involuntary emissions in sleep are most probably the usual and natural means whereby the burden of unappropriated secretion is got rid of.

The answer to the second question is as follows. There is strong reason to believe that man, in common with brutes, is subject to a periodic rut, an alternation of sexual excitement and quiescence, occurring at short intervals. During the period of excitement spermatozoa are becoming rapidly adult, the testicles and their ducts are full of semen, the individual is in the condition of a fish with a full milt, or a bird or stag with enlarged testicles. He now instintively seeks the society of women (these things are not so much matters of chance as is generally imagined, and the testicles may be blameable for much of what is usually ascribed to the heart). Lascivious dalliance increases his excitement, and all is ready for the copulative act. There is reason to believe that one vas deferens alone furnishes the semen for one copulation, the other vas supplies another emission; but after a few encounters, some of them perhaps without effect, a period of rest is required to secrete and perfect a fresh store of semen. The duct of the testicle is the only reservoir, and for that reason, combined with the unlikelihood of the impromptu secretion of semen, I formed the opinion cited above, that the quantity of actual secretion of the testicles emitted in one copulation is probably so small as to require augmentation by some congenial fluid.

Hunter remarks, — "We have a presumptive proof that the semen can be absorbed in the body of the testicle and in the epididydimis, and that the vesiculæ secrete a mucus which they are capable of absorbing when it cannot be made use of. We may likewise infer from what has been said, that the semen is not retained in reservoirs after it is secreted, and kept there till it is used, but that it is secreted at the time, in consequence of certain affections of the mind stimulating the testicles to this action; for we find that if lascivious ideas are excited in the mind, and the paroxysm is afterwards prevented from coming on, the testicles become painful and swelled, from, we may suppose, the quantity of semen secreted, and the increased action of the vessels, which pain and swelling is removed immediately upon the paroxysm being brought on and the semen evacuated; but, if that does not take place, the action of the vessels will still be kept up, and the pain in the testicles in general continue till the paroxysm and evacuation of the semen is brought on, to render the act complete; without which a stop cannot be so quickly put to the action of the vessels that produce the secretion, nor the parts be allowed so easily to resume their natural state. There is at this time no sensation of any kind felt in the seat of the vesiculæ seminales, which shows that the action is in the testicles, and in them alone. The pain in the testicles, in consequence of being filled with semen and, of the action being incomplete, is sometimes so considerable as to make it necessary to produce an evacuation of the semen to relieve the patient." Hunter was not aware of the highly elaborated character of the seminal fluid, or he would probably not have so readily accepted the idea of the semen being secreted "at the time." The "lascivious ideas" which he mentions are probably an effect or concomitant of seminal repletion rather than a cause, yet becoming, perhaps, an additional cause in their turn.

Many interesting arguments in relation to this subject might doubtless be derived from the manner of copulation of different animals; but this is an occurrence in the natural history of species which authors have entirely left unnoticed, probably from feelings of delicacy. This want is felt as a great desideratum by the comparative anatomist, in investigating any of the accessory parts of generation, where the manner of coition unavoidably forces itself upon our consideration, malgré the delicacy, which everybody feels, but which the physiologist is bound to suppress when he handles such subjects. As a sample of such arguments I may adduce the following. The prolonged coition of the dog, which is destitute of vesiculæ, was formerly much dwelt upon in support of the pre-Hunterian view of the receptacle-function of these sacs. But is the act prolonged in every animal destitute of vesiculæ? I have been told that the copulation of cats is very quickly completed; and cats are as destitute of vesiculæ as dogs. On the other hand, the boar is very long in coition, although his vesiculæ are very large and complicated. Such reasonings on the facts of comparative anatomy are, indeed, very unsafe, unless the number of facts observed is very great, and that is not the present condition of our knowledge of the copulative act. For that reason I have not dwelt upon this, *primâ facie* so obvious, line of argument.

Our knowledge of the function of the vesiculæ seminales is, therefore, nearly in the same condition as it was left by the great Hunter, whose concise paper on this subject is a master piece of reasoning and scientific acumen. I have been able to add to this, besides confirmation, little more than some few observations tending to render it more probable that the secretion of the vesiculæ is used in copulation. I have, further, ventured on an hypothesis which, I suppose, has suggested itself to many before, and with which I am by no means satisfied. So great, however, are the difficulties surrounding the subject, that in this unsatisfactory state — the positive function still hypothetical — I am compelled reluctantly to leave it.

(*S. R. Pittard.*)

VISION. — (Fr. *vision*, from Latin *visio*, from *video*, *visus*, sight.) — The faculty of seeing is one of the chief means by which living creatures are brought into relation with the world around, and is the especial means by which they are enabled to appreciate the wonderful phenomena which flow directly and indirectly from the creation of light. When in obedience to the Divine command, "There was LIGHT," there were organs created for its perception; and it is interesting to observe that the restoration of this gift of perception, when lost, was among the most frequent, and certainly not the least striking of the manifestations of miraculous power displayed by the Saviour of mankind. The vastness of the field over which the faculty of vision gives us command, the precision and permanence of this class of our perceptions, the variety and accuracy of the information it conveys, and the delight it affords, lead us irresistibly to regard it as the most perfect of our senses. In the investigation of this subject a train of minute adaptation and wonderful contrivance is disclosed to us, in which are combined the extremes of grandeur and of delicacy. There is no department of science that possesses a more absorbing interest than the laws of optics when applied to the eye, and certainly none which points with a steadier hand to the wisdom of an omnipotent Creator.

Very curious and unexpected information respecting the early condition of the surface of this planet and the ancient atmosphere has been afforded by an investigation into the structure of the organs of vision with which the earliest marine animals were supplied. In the eloquent language of Dr. Buckland, "with respect to the waters wherein the Trilobites maintained their existence throughout the entire period of the transition formation, we conclude that there could not have been that imaginary turbid and chaotic fluid, from the precipitate of which some geologists have supposed the materials of the surface of the earth to be derived: because the structure of the eyes of these animals is such, that any kind of fluid in which they could have been submerged at the bottom must have been pure and transparent enough to allow the passage of light to organs of vision, the nature of which is so fully disclosed by the state of perfection in which they are preserved. With regard to the atmosphere also, we may infer that had it differed materially from its actual condition, it might have so affected the rays of light, that a corresponding difference from the eyes of existing Crustaceans would have been found in the organs on which the impressions of such were then received. Regarding light itself, also, we learn, from the resemblance of these most ancient organizations to existing eyes, that the mutual relations of light to the eye and of the eye to light, were the same at the time when Crustaceans endowed with the faculty of vision were first placed at the bottom of primæval seas as at the present moment."

Light. — To the opinions of the ancients on the subject of light but little allusion need be made, as they were but crude and vague conjectures. One, for instance, supposed that the eyes emitted emanations of some sort by which objects were, as it were, felt. Others imagined that visible objects were constantly throwing out from them spectral resemblances of themselves, which, when received by the eye, produced an impression of those objects; but in these fanciful notions there is little satisfaction, and we proceed at once to the hypothesis of our illustrious countryman, Sir Isaac Newton. According to his theory, light was an imponderable substance, whose inconceivably minute particles produced the sensation of light by their action on the eye: moving with immense velocity, they were nevertheless acted on by attractive and repulsive forces residing in all material bodies, and by these forces were liable either to be turned aside from their natural straight course, reflected by the repulsive force, or penetrating between the particles of bodies, to take a direction on quitting them finally determined by the position of the surface at which they emerged. About the same time, however, a very different hypothesis was advanced by Huyghens, to the effect that all space is filled with an extremely elastic and rare ether, and that light is the result of the undulatory movements communicated to this ether by self-luminous bodies, which movements being transmitted to the optic nerve, give rise to the sensation of light. The beautiful experiments of Dr. Thomas Young strongly confirmed the truth of this theory, which is based upon the supposition that light acts by vibrations upon the retina, in the same manner as the undulations of the air striking upon the tympanum excite the sensation of sound.

The *velocity* of the luminous undulations deduced by Römer from the eclipses of the satellites of Jupiter, is proved to be about 192,500 miles in a second: in other words, light travels a distance equal to eight times the circumference of the earth, between two beats of a clock.

That white light was supposed by Newton to be *composed of seven colours* is too well known to need description here; but the proportion of each colour, according to the observations of Newton and Fraünhofer, is as follows:—

	Newton.	Fraunhofer.
Red	45	56
Orange	27	27
Yellow	40	27
Green	60	46
Blue	60	48
Indigo	48	47
Violet	80	109
	360	360

It is to Sir David Brewster that we are indebted for our knowledge of the fact, that the solar spectrum in reality consists of only three primary colours, *red*, *yellow*, and *blue;* each of which exists throughout the whole of the spectrum; and that the super-position of these in different degrees of intensity in different parts produces the seven hues. The proportion in which the primary colours combine to form white light, is:—

Yellow, three parts.
Red, five parts.
Blue, eight parts.

All the seven hues are possessed of different degrees of refrangibility; the red being least refrangible, the violet the most. It appears from Sir John Herschell's experiments that just beyond the violet there exists a band of coloured light of still greater refrangibility, which he has denominated the *lavender* band. The same great philosopher has also proved that the coloured rays in the spectrum differ materially in the length and rapidity of their undulations.

Coloured rays.	Length of luminous rays in parts of an inch.	Number of undulations in an inch.	Number of undulations in a second.
Extreme red	0·0000266	37640	458 Mill. of Mill.
Red	·0000256	39180	477 ,,
Intermediate	·0000246	40720	495 ,,
Orange	·0000240	41610	506 ,,
Intermediate	·0000235	42510	517 ,,
Yellow	·0000227	44000	535 ,,
Intermediate	·0000219	45600	555 ,,
Green	·0000211	47460	577 ,,
Intermediate	·0000203	49320	600 ,,
Blue	·0000196	51110	622 ,,
Intermediate	·0000189	52910	644 ,,
Indigo	·0000185	54070	658 ,,
Intermediate	·0000181	55240	672 ,,
Violet	·0000174	57490	699 ,,
Extreme Violet	·0000167	59750	727 ,,

From this table it will be seen that the sensibility of the eye is confined within much narrower limits than that of the ear, the ratio of the extreme vibrations being nearly 1·58 : 1, therefore less than an octave, and equal to a minor sixth.

Sir William Herschell discovered that there are rays in the solar spectrum which give rise to the sensation of heat, independently of those of light, and these *calorific* rays are most abundant a little beyond the red extremity of the spectrum, and gradually diminish towards the violet, beyond which they are imperceptible; an important practical fact has recently been discovered in relation to these rays. It is well known that plants growing in stove houses often suffer from the scorching influence of the calorific rays, and when the great palm-house at Kew was about to be erected, an elaborate series of experiments was undertaken by Mr. R. Hunt, to ascertain whether it would not be possible to cut them off by means of a tinted glass. In this he was fully successful, and discovered that a glass tinted of a very pale yellow-green colour by oxide of copper completely prevented the permeation of all that class of heat rays which exists below, and in the point fixed at that of maximum calorific action; as it is to this class of rays that the scorching influence is due, the use of the glass described has effectually protected the plants. The absence of oxide of manganese commonly employed in all sheet glass, is insisted on, it having been found that such glass will, after exposure for some time to intense sun-light, assume a pinky hue, which is highly objectionable.

To Dr. Wollaston we owe the discovery of the existence beyond the extreme violet of *chemical* rays, which are known to us solely by their effects. It is to their action that the fading of vegetable colours, and the blackening of nitrate of silver, is due. The influence of these chemical rays extends throughout the spectrum, and to it the term *actinism* has been applied. From the experiments of Mr. Hunt it appears that actinism exercises an important influence on the vegetable world, exciting the germination of seeds, and being essential to the formation of the colouring matter of leaves. The actinic principle is most energetic in spring, when its stimulus is required to rouse dormant vegetation from the repose of winter: as soon as this is effected, the luminous rays, with the advance of the sun, become more active, and the formation of woody fibre proceeds under their particular agency; but in autumn, the actinic power having performed its part, is no longer required, the whole energy of vegetation being concentrated under the influence of the calorific rays in the ripening of fruits and perfecting of seeds. It has been long known that the calorific and luminous rays were capable of extinction by means of polarisation, but it has only been very recently ascertained by Professor Wartmann that the chemical rays are equally amenable to polarisation under similar conditions.

Those diversified colours which render the floral world so attractive, which impart such beauty to the feathered tribes and the legions of butterflies, and in brilliant pigments reward the labours of the chemist, are not properties inherent in matter itself, but arise from the *action of matter upon light*, whereby certain of the coloured rays which form white light are reflected, whilst others are absorbed or transmitted. Scarlet cloth, for instance absorbs almost all colours except red, which it reflects; but those substances which reflect all the rays appear white; those which absorb all are black. The brilliancy of tints is greatly increased when viewed in light of their own colour, as may be proved by throwing the red rays from a prism upon any scarlet object, or the green rays upon a green leaf. The colour of transparent substances depends upon their property of absorbing some of the colours of white light, and transmitting others. The blue tint of the atmosphere in reflected light, and its red morning and evening tinge, are to be ascribed to this cause.

Dyes and paints are substances which, when applied to bodies, so change their surfaces, that when seen in white light, they reflect only the particular colour of the dye or paint. There are several modes by which white light can be reproduced, of which a simple one is, the rapid rotation of a disk painted in stripes, with the prismatic colours in the correct proportions. In this case, the eye receives the impression at the same time, and in the same place, of a red circle, an orange, a yellow circle, and so on, and consequently a white circle, since the sensation of white is but the simultaneous sensation of all these colours.

As in the production of white light, it is necessary that all the simple colours should exist in their due proportions; so it is evident that by suppressing or increasing one the harmony will be destroyed, and the light will be no longer white. Thus, for instance, by suppressing red, we obtain a blueish green, which, compounded with red, would form white light. Whenever two colours, simple or compound, fulfil this condition, they are said to be *complementary* one to the other. They are as follows:—

Colour.	Complementary.
Red - - -	Blueish-green.
Orange - -	Blue.
Yellow - -	Indigo.
Green - - -	Violet-reddish.
Blue - - -	Orange-red.
Indigo - - -	Orange-yellow.
Violet - - -	Yellow-green.
Black - - -	White.
White - - -	Black.

With respect to the production of light, bodies are divided into luminous and non-luminous; among natural bodies some possess in themselves the property of exciting in our eyes the sensation of brightness, or light, as the sun and other heavenly bodies which shine by their own light. There is also *chemical* light, or that produced by combustion, *electric* light, *phosphorescent* light, *et cetera*. Non-luminous bodies are such as become visible only when light falls upon them from some luminous source.

Bodies are also divided into *transparent and opaque*, in reference to their capacity for transmitting light through their substance, though this property depends, not merely on their absolute transparency, but also on the density of the medium through which the light passes. There is no perfectly opaque or perfectly transparent substance known. Diamond is nothing more than charcoal in a different state of molecular aggregation, and gold can be made pervious to light. On the other hand, the purest air or clearest water gradually extinguishes by absorption the rays transmitted through them. According to Bouguer the purest sea water loses all its transparency at a depth of 730 feet, and the reason that more stars are visible from the summit of a lofty mountain than from the level of the sea is, because the light from the more distant stars becomes so much enfeebled during its passage through the lower strata of the atmosphere, that it has not sufficient power to affect the sight.

If a pencil of rays diverging from a luminous point fall upon the surface of a convex lens, they will not all be equally *refracted*. The ray which passes through the axis of the lens will not be changed in its course, but the remainder of the rays will be more and more refracted in proportion as they recede from the optical centre of the lens. When the rays pass out from a bi-convex lens into air they are refracted from a line perpendicular to the point of emergence: the effect is to cause them all to converge towards the central ray to a point at which they meet, called the *focus*. The distance between the focus and the refracting surface is the *focal distance* or *focal length*, and is influenced by the refracting power of the lens, the amount of its curvature, and the distance of the luminous body.

Parallel rays entering any plano-convex or double convex lens at an equal distance from its axis, are concentrated to the same focal point, but as the peripheral rays are more refracted than the central rays, they are sooner brought to a focus; hence the image formed at the focus of the lens is somewhat indistinct at its edges. This imperfection is due to what is termed *spherical aberration*, and is counteracted either by shutting out the peripheral rays, or by such a combination of lenses as will establish a just proportion between the refraction of the central and peripheral rays. Such lenses are made of crown glass, composed of flint and alkali only, and flint glass, in which oxide of lead is added to the other materials. The latter possesses a much higher dispersive power than the crown glass; but the refraction of the rays is nearly the same in both, and when combined, *achromatic* lenses are obtained. This term is applied from their utility in obviating another source of confusion, *chromatic* aberration, which is caused by the unequal refrangibility of the prismatic rays when transmitted through an ordinary lens, whereby the images are fringed with colours, and are rendered even more indistinct than by spherical aberration. Newton supposed that an achromatic lens was an impossibility; but in 1757 Dollond completely succeeded in overcoming the difficulty by the combination of crown and flint glass. He supposed the mean refractive power of flint glass, as compared to crown glass, to be 158 to 153; Fraünhofer states it to be 164 to 153. The prismatic dispersion in English flint glass is $1\frac{1}{2}$ times, but in Fraünhofer's, it is twice as great as in crown glass.

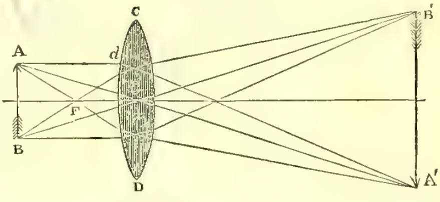
Such are the chief facts concerning light, which bear reference to vision: to the consideration of the physiology of which we now proceed.

Phenomena of Vision. — The special function with which the retina is endowed being the perception of light, a marvellous range of phenomena is open to the inquirer. It is indeed a wonderful thing to have ascertained beyond doubt, that in perceiving the tint of the scarlet geranium our eyes are affected by undulations recurring four hundred and eighty-two millions of millions of times in a second; that before we can appreciate the tint of the yellow blossoms of the gorse or laburnum, five hundred and forty-two millions of millions of vibrations must have taken place; and that to discriminate the colour of the violet, not less than seven hundred and seven millions of millions of movements must have been communicated to the fibrillæ of our retinæ! Whilst such facts almost transcend the powers of human conception, their establishment is a striking triumph of human intellect. But how great ought to be our admiration of that Omnipotence which has endowed the eye with the gift, not merely of appreciating one colour, but of distinguishing, in all their shades, the inexpressibly complicated vibrations which mark the hues of a parterre of flowers, and characterise the gorgeous plumage of the birds which give animation to a tropical forest. The sense of sight, in its ordinary acceptation, may be defined as the recognition by the mind of certain impressions made upon the retina, and communicated through the medium of the optic nerve to the encephalon; a sound condition of each and all of these parts (which may be considered as the media of communication, so far as one sense is concerned, between the external world and the mind) is indispensable for perfect vision. Light may fall upon the retina, and the images of objects may be there depicted, but should the optic nerve be unsound, or certain portions of the brain be disorganised, no responsive image is called up before the mind; the eye may gaze upon the noonday sun, but all is dark within.

The natural stimulus of the retina is the luminous rays: the appreciation of light and colour its active condition; and its state of repose suggests the appearance of darkness: but besides light, any other excitement applied to the retina or optic nerve gives rise to the same result, — the production of luminous appearances. Pressure upon the eye-ball, the electric current, or vascular congestion, all excite this special phenomenon. Occasionally, too, irritation of the brain has the same effect; and many are the waves and corruscations, the fiery clouds and flaming spectra, which haunt the amaurotic when certain morbid complications exist. The phantasms of fever, and the illusions of the dying, are to be placed in the same category with the above.

For visual purposes, a certain amount of stimulation of the retina is necessary; hence it is both difficult and painful to discern objects in very faint light: but in this respect the retina is endowed with great powers of accommodation. It is well known that persons long immured in dungeons profoundly dark to ordinary eyes, have acquired the power of discerning the most minute objects. On the other hand, excessive light is injurious, for by it vision may be instantaneously extinguished, as happens by a stroke of lightning. The accommodation to various amounts of light is, however, gradual, as is proved by passing from a dark room into sunlight, or into a brilliantly lighted apartment. In this case the pupil has been widely dilated to admit the greatest possible quantity of light into the eye. For the first second or two after arriving in the light, all is confusion; and there is even pain, from the flood of light which thus breaks in on the retina through the widely dilated pupil, and takes it, as it were, unawares. On the other hand, a person entering a moderately dark room from full sunlight, sees nothing for a time, because the strongly contracted pupil admits so little light, that no sensation is produced. After a while the pupil dilates, and vision gradually becomes complete. In order that a clear idea may be formed of the mode in which images are depicted upon the retina, and also of the causes of myopia and presbyopia, it is necessary that the mode of action of convex lenses should be described.

Fig. 884.



Let C D be a biconvex lens, and A B an object on one side of it, but further removed than the focal point F. Every point of the object will send forth rays in all directions, but to avoid confusion, we will only consider those flowing from the extremities A B. The rays emitted from A undergo refraction, are altered in their direction, and are united at A′ upon the secondary axes drawn from A through G, the centre of the lens. The rays from B are in like manner united at B′; consequently, A′B′ is the image of the object A B, but inverted. Seen from the middle of the lens, the image and object appear at the same angle, for the angle B′G A′ is equal to the angle B G A, being angles at the vertex. The relative size of the object or the image depends upon the relative distance of each from the lens. If the object lie twice as far as the focal distance from the lens, the image will be formed on the other side at an equal distance, consequently the image and the object are equal in size. But if the object approach nearer to the glass, the image will recede, becoming larger. We thus obtain inverted and enlarged images of objects standing further from the lens than the focal distance, yet not so far as twice that distance. Thus the image A′B′ is larger than the object AB. If the object be further removed from the glass than twice the focal distance, the image will be nearer; we therefore obtain inverted diminished images of distant objects.

Dioptric phenomena.—Krause has described the anterior surface of the cornea as being spherical, the posterior parabolic. We recently had an opportunity of examining a human cornea in less than an hour after the eye had been extirpated from the living subject, and satisfied ourselves that, in that case at least, the two surfaces were perfectly parallel. According to Chossat the figure of the cornea is an ellipsoid of revolution about the major axis, which axis determines the axis of the eye. The ratio of the semi-axis of this ellipse to the excentricity he determines at 1·3; and this being nearly the same with the index of refraction, parallel rays incident on the cornea in the direction of its axis will be made to converge, with great exactness, to a focus situated behind it, the aberration, which would have existed had the external surface been of a spherical figure, being almost completely destroyed. The form of the crystalline lens is that of a solid of revolution, having its anterior surface much less curved than its posterior: by some authorities both surfaces are described as being ellipsoids of revolution about their lesser axes; but Krause found the posterior surface to have a parabolic curve, whose parameter was from $3\frac{4}{5}'''$ to $5'''$. He found also that the elliptical curve of the anterior surface of the lens varied as regards its long axis, in different cases from $4'''$ to $5\frac{1}{10}'''$; its short axis also varying from $1\frac{2}{3}'''$ to $2\frac{1}{4}'''$. Dr. Albert de Gräefe informs us that he has repeated these observations, and ascertained them to be correct. Valée states that he has found by a comparison of Krauss's measurements of the dimensions of the eye, that the exterior convex surfaces have exactly that geometrical form which produces foci free from deviations. He calls them optoidal surfaces, and also finds that the posterior convex surfaces are at least so far optoidal, as the pencils of light penetrating into the eye infringe upon them. The axes of the two surfaces of the lens are not exactly coincident in direction with each other, nor with that of the cornea.

The refractive index of the surface of the lens is, according to Brewster, 1·3767; of the centre 1·3990, the mean being 1·3839: that of the vitreous humour is 1·3394; thus the refractive density of the lens being greater than that of either the aqueous or vitreous humour, it exercises an important influence on the converging rays incident on it from the cornea. The effect of its elliptic figure is probably to correct the aberration of oblique pencils, and general aberration is still further obviated by the peculiar and varying density of its substance. By Professor James Forbes the variable density is supposed to alter the figure of the lens under pressure, and so to assist in focal adjustment.

As the rays refracted by the aqueous humour pass into the crystalline, and those from the crystalline into the vitreous humour, the indices of refraction of the separating surface of these humours will be, according to Brewster:—

From aqueous humour to outer layer of crystalline - - - -	1·0466
From ditto to crystalline, using the mean index - - - -	1·0353
From vitreous to crystalline outer layer - - - - -	1·0445
From ditto to ditto, using the mean index - - - - -	1·0332

Suppose, then, the eye to be directed towards an object, the rays of light proceeding from that object are thus disposed of. Those which strike the cornea very obliquely are reflected, as are those which impinge upon the sclerotic; a large proportion of the rays, however, pass through the cornea, being powerfully refracted by it, and the aqueous membrane, and less by the aqueous humour behind: proceeding onwards, many of the rays are arrested by the iris, some being absorbed, others reflected, conveying the colours and brilliancy characteristic of that membrane. The more central rays pass through the pupil and the crystalline lens. The layers of this body, increasing in density from the circumference to the centre, resemble in their effect upon the rays the atmosphere of this earth, which causes a gradual bending of the rays flowing from the heavenly bodies; so the crystalline lens by its form and structure gradually but powerfully increases the convergence of the rays which penetrate it, both on their entrance and their exit. They then traverse the vitreous humour, — the chief use of which appears to be to afford support to the expanded retina, —and are brought in a perfectly natural eye, to foci upon the retina, forming there an exact but inverted picture of the object. If the eye of a white rabbit or any other albino be carefully cleansed, the flame of a taper held before the cornea may be seen inverted at the back of the eye, increasing in size as the taper is brought near, diminishing if it retires, and ever moving in the direction opposite to that given to the flame.

Such, in general terms, are the phenomena attending the formation of images in the eye; and they are strictly in accordance with the mode of action of convex lenses, of which the rule is, that an image formed by a convex lens is inverted, and its position relatively to the position of the object and its magnitude, are to that of the object as its distance from the lens is to the distance of the object from the lens. The rays composing a pencil falling upon the cornea, are refracted by the transparent media of the eye in proportion to the difference between the density of these media, and that of the air, and in proportion to the curves presented by their several surfaces. It is of course the central ray only, or that which passes through the axis of the eye, that is not refracted; all the other rays undergo refraction, and are approximated to the central ray. The prime rays have been termed rays of direction, because every prime or axial ray determines the direction of the other rays. As every object emits rays, from every point, in all directions, which rays then proceed in straight lines, it necessarily follows that, undergoing these refractions, there must be some point in the eye at which the axial rays of the different pencils, proceeding from the object, cross; and this appears to be very near the centre of the eye, somewhat behind the crystalline. Sir D. Brewster places it in the geometric centre of the eye-ball, consequently a little within the crystalline lens; and Volkmann has described the point of intersection as being $3'''$ 97 behind the cornea, $0'''$ 43 before the posterior surface of the crystalline, and $6'''$ 23 in front of the retina. Other and very careful observers, however, place it at a very short distance behind the crystalline lens. It is called the *focal centre*, and the angle formed by the intersecting axial rays from two points is the *visual angle*. This focal centre seems, according to the researches of Ruete, to be of importance in another way. In the steady contemplation of objects, we have to bring them into the focal centre of the produced visual axis; and in the motion by which this is accomplished, it would appear that the eye revolves accurately round a point, which point of revolution is the focal centre of the eye. In vision, the muscles of the two eyes act under the influence of the will, with a remarkable and admirable sympathy; and it is on this harmonious consent, as it were, of opposing muscles, that vision in its most perfect form depends.

Vision under water is attended with some curious consequences, the result of what is termed "internal" reflection. An eye placed under perfectly still water, as for instance, the eye of a diver, will see external objects only through a circular aperture (as it were) of $96° 55' 20''$ in diameter overhead. But all objects down to the horizon will be visible in this space; those near the horizon being much distorted and contracted in dimensions, especially in height. Beyond the limits of this circle will be seen the bottom of the water, and all subaqueous objects reflected and as vividly depicted, as by direct vision; and in addition, the circular space above mentioned will appear surrounded with a rainbow of faint but delicate colours. In the eyes of fishes, the humours being nearly of the refractive density of the medium in which they live, the action of bringing the rays to a focus on the retina is almost entirely performed by the crystalline lens, which is nearly spherical and of small radius in comparison with the whole diameter of the eye; there is also a very great increase of density towards the centre, whereby spherical aberration is obviated, the corneal refraction having little influence.

When speaking of light we have mentioned spherical and chromatic aberrations; and it is necessary that they should be again alluded to in reference to the eye. Spherical aberration is beautifully counteracted by the figure and varying density of the crystalline lens; which, increasing in refractive power towards the centre, refracts the central rays in each pencil, to the same point as its external rays: but an important agent in obviating this aberration is the iris, which is, as it were, perpetually on the watch to limit the rays entering the eye to those which produce a perfect image, cutting off others which, by their obliquity of incidence, might occasion the imperfection in question. Opticians endeavour to obtain the same effect in their instruments by the employment of an opaque screen or diaphragm; but no device of human art can equal the ever changing pupil of the living eye.

Sir David Brewster, and some other authorities, deny that the eye is perfectly free from *chromatic* aberration: and it is certain that when the pupil is dilated by belladonna, and the lateral rays freely admitted, coloured fringes are perceptible, as we have ourselves experienced; on the other hand, the forms and relative densities of the humours of the eye closely imitate the achromatic combination of lenses, for the two menisci, formed by the aqueous and vitreous humours, having the double convex crystalline lens, of greater density than either, placed between them, fulfil these conditions very happily, and can hardly fail to obviate, in a material degree, *chromatic* aberration. The coloured fringes we have spoken of, as being produced by the dilatation of the pupil, must not be confounded with the chromatic images, which depend on certain conditions of the retina. The former are always connected with refraction, and they attach particularly to two conditions, namely, the falling of a light close to a shadow, and the projection of the limits of either on the retina, in such a way that all sharpness of outline is lost. The transition from light to shade—the blending of the light and darkness thus produced—gives rise to coloured fringes. This may be shown by taking up a position, at the end of a room, before a brightly illuminated window, and holding up any small object, such as a pencil, before the eye, which must be steadily fixed upon the window-sash. Presently prismatic colours appear on either side of the bars as well as of the pencil. Goethe explained all chromatic phenomena on the sole ground of modifications in light and shade. In the light seen through dull media, according to his theory, yellow is first perceived, then in succession, red, pale blue, blue, violet, black blue, and black; and he explains dioptrically-formed coloured margins from the subjective side, by a mutual encroachment of the light and dark, the shadow before the light being perceived as blue and violet, and the light before the shadow as red and yellow.

Distinct vision. — Dugald Stewart, in his "Philosophy of the Human Mind," proposes this question: Suppose the eye to be fixed in a particular position, and the picture of an object to be painted on the retina, does the mind perceive the complete figure of the object at once, or is this perception the result of the various perceptions we have of the different points in the outline? He arrives at the conclusion that the mind does at one and the same time perceive every point in the outline of the object, for perception, like consciousness, is an involuntary operation: as no two points, however, of the outline are in the same direction, every point by itself constitutes a distinct object of attention to the mind; but these acts of attention are performed with such rapidity, that the effect is the same as if the perception were instantaneous. When the eye is directed to any point of a landscape, it sees with perfect distinctness only that image of it which is directly in the axis of the eye; but the extreme mobility of the eye, together with the duration of the impressions upon the retina, enable us to take in every part of the view with equal distinctness. In all probability, it is only in the axis of the eye, corresponding with the yellow spot, that vision is *perfect;* the posterior part of the retina is certainly better adapted to receive images than the anterior, where the grey nervous layer becomes thinner and thinner towards the border. Dr. Young calculated that the range of motion in the eye-ball is 55° in every direction, so that the head being fixed, a single eye may have perfect vision of any point within a range of 110°. He further ascertained, by fixing the eye in the most natural direction, namely, forwards, and a little downwards, and by then moving a luminous object before it in various directions, that the range of vision upwards was 50°, downwards 70°, inwards 60°, and outwards 90°, giving an entire horizontal play of 150°, and a total vertical play of 120°.

The small portion of retina corresponding to the extremity of the optic nerve, is insensible to visual impressions. Volkmann states that he has satisfied himself by calculation that the small insensible spot corresponds exactly with the dimensions of the central artery. Dr. Young determined that the distance of the centre of the optic nerve from the visual axis is $\frac{16}{100}$ of an inch, and that the diameter of the most insensible part of the retina is $\frac{1}{30}$ of an inch. It is to be borne in mind that the fibrous lamina of the grey nervous layer of the retina is at this point evolving itself from the nerve, and is not yet invested with the vesicular or other laminæ. Mr. Bowman has well remarked that this incapacity of vision at the entrance of the optic nerve seems to be essential to the mode of junction of the retina with the nerve, since it appears to have been the chief reason why the nerve was not made to enter in the axis of the eye. If the blind spot had been situated in the axis, a blank space would have always existed in the centre of the field of vision, since the axis of the eyes in vision are made to correspond. But as it is, the blind spots do not correspond when the eyes are directed to the same object; and hence the blank which one eye would present, is filled up by the opposite eye. Mariotte, was the first who described the existence of these blind spots, and they may be discovered by the following simple experiment: — Let two black dots be placed one inch apart on a sheet of white paper: if the left eye be closed, and the dots are regarded at the usual distance for distinct vision, the attention, however, being particularly directed to that on the right hand, the other dot will be found to disappear the moment the pencil of rays proceeding from it falls upon the centre of the entrance of the optic nerve.

It has been already stated, that when the rays from an object meet in foci on the retina, a distinct image is formed: should the focus, however, be before or beyond the retina, it is evident that some indistinctness must be caused, for each point of the retina would then receive rays from several points of the object. It is to be borne in mind, that the nearer the object to the eye, the greater is the divergency of the incident rays; and the greater their divergency, the more distant is their focus. When the retina corresponds, or nearly corresponds, to the points of convergence of the several pencils of light, distinct vision is obtained, the usual distance being from eight to ten inches, at which distance, reading or writing is naturally performed. If, when writing, for instance, we removed the head further, or approached it nearer, and no alteration took place in the eye, vision would become indistinct, because the focus would be altered, and would either fall short of, or be thrown beyond, the retina: should the rays, however, very nearly unite upon the retina, vision, of large objects especially, may prove sufficiently distinct, though not perfectly clear. A just distinction was, therefore, drawn by Jurin between *perfect* vision and *distinct* vision, the perfection of vision depending on the distance alone of objects, whilst their distinctness would be regulated not less by their size, than by their distance from the eye.

The pupil of the eye performs an important part in enabling us to see objects distinctly. When looking intently at a near object, the pupil contracts, thereby limiting the rays which pass through it to the most central, and stopping the progress of those more divergent rays which, not converging to foci on the retina, would cause circles of dissipation; upon the same principle, vision of near objects is assisted by a pin-hole aperture. Let a person thrust a pin through a card, and make a clean hole; then let him hold a book so close to his eyes that the type becomes confused; if he now looks through the pin-hole, he will again see it distinctly, because the card answers the same purpose as a further contraction of the pupil, arresting the progress of those rays which are too divergent, and limiting those entering the eye to the central rays, which, from their trifling divergence, unite correctly on the retina. The same advantage is gained by a near-sighted, and by a presbyopic eye. In the one case vision is improved by the card stopping the rays, which would converge to foci in front of the retina; in the other, by its arresting those which tend to foci behind the retina. So that this simple experiment frequently makes a difference of several inches in the vision of myopic and presbyopic persons.

A curious experiment devised by Father Scheiner, has reference to this point. If we make in a card two small orifices with a needle, at a less distance from each other than the diameter of the pupil, and hold these openings close to the eye, a double image of a small object held within the visual distance, — a pin's head, for instance — will be seen. From the pin's head there pass two very minute pencils of rays through the apertures into the eye. These rays converge towards a point lying behind the retina, and fall upon the retina at two different points. These are two isolated points of the circle of dispersion, which would exist upon the retina, if the other rays were not intercepted by the card. If we now withdraw the pin's head more and more, the images will approach, because the rays, falling upon the eye through the apertures, will diverge less, and will consequently be refracted towards a point lying nearer to the retina. If the object be removed from the eye to the distance of distinct vision, the two images will perfectly coincide, since all rays passing from one point, lying exactly at the distance of distinct vision, will be concentrated at one point of the retina. It may be asked, what are the conditions of adaptation necessary for an eye in looking through a fine aperture? In its normal condition, for the maintenance of which no effort is necessary, the eye is in the state necessary for seeing objects which lie at the distance of distinct vision. If a distant object be regarded through the small apertures, the rays passing through them into the eye must evidently meet at one point before the retina, as the condition of each adaptation does not change in the eye: but the two pencils diverge again behind the point of intersection, striking the retina at two different points, when, consequently, distant objects will be seen double; therefore, we only see a small object single, through two small apertures, when it lies at the distance of distinct vision.

This experiment of Scheiner led Dr. Porterfield to invent an instrument called an *optometer*, for the determination of the focal distance of the eye; and Dr. Young subsequently greatly improved upon it, his instrument being simple in construction, and both convenient and accurate in its application.

The greatest distance of human vision is so variable, that no arbitrary limits can be assigned to it. Uncivilised tribes, as the North American Indians, the inhabitants of the immense Asiatic steppes, and the New Zealanders, possess powers of sight which are almost incredible. It is interesting, however, to remark, that the mean degree of capability of vision was the same among the ancient Greeks and Romans as at the present day. The Pleiades furnish the proof of this, showing that some thousand years ago, as now, stars which astronomers call of the seventh magnitude, were not visible to the naked eye in persons of ordinary powers of vision. Even among civilised nations, however, instances are occasionally met with of extraordinarily keen sight. General Drinkwater, in his "History of the Siege of Gibraltar," mentions that there were two boys in the garrison possessed of such uncommon quickness of sight, that they could see the shots fired by the enemy almost immediately after they had quitted the guns, and were constantly employed to look out and give warning to the soldiers of the approach of these missiles.

From the experiments of Harris, it seems that a simple object, as a black square on a white ground, or a white square on a black ground, can be seen under a less angle than the equal parts of a compound object, as the squares of a chequered figure, and that their least, or minimum visible angle cannot be less than 40″: others, however, say 30″. If it is 40″, the size of the image on the retina will be $\frac{1}{8000}$ inch. At a medium, Harris thinks it not less than 2′. He remarks that the difficulty of keeping the eye perfectly steady, may be one cause why a single object can be discerned under a less angle than the parts of a complex one; and that it is natural to suppose that the fewer objects we contemplate, and the more they differ in colour, the easier we can distinguish their several impressions on the retina. The result of repeated and very careful experiments by Hueck, tends to show that white objects on a black ground are seen at a greater distance than black objects on a white ground *, and this is fully corroborated by an instance mentioned by Humboldt. This distinguished traveller was with Bonpland, at

* The following facts, deduced from extensive and very careful experiments, conducted by Lieut.-Colonel Hamilton Smith, are of great practical importance. The object was to ascertain the liability of different colours to be hit as marks, under precisely similar circumstances, as to men engaged, size of target, weather, &c. The result showed the proportion to be as follows. —

Red, 12. Rifle-green, 7. Austrian blueish-grey, 5.

Colonel Derinzy, who was actively engaged in the Peninsular War, has given much attention to the effect of different coloured uniforms on the chances of being hit. The day before the battle of Vittoria, his Portuguese rifle company, dressed in earthy-brown, and a company of British Fusileers, of equal strength, dressed in red, had to dislodge the French from a bridge. They were equally exposed during the whole of the skirmish, and after it was over, Colonel Derinzy compared notes with his Fusileer comrade, and found that the relative losses were precisely *one to two!* This fact (for which we are indebted to Captain Nelson, R.E.) strikingly

Chillo, near Quito, in South America, from whence the long extended ridge of the volcano of Pichincha is visible. Bonpland had proceeded on an expedition to the volcano, and Humboldt, with others, was somewhat anxiously looking out for him. The Indians of the party recognised the traveller as a white point moving along the face of a black basaltic precipice, before he was discovered by Humboldt and others, who were looking out for him with telescopes (a proof, by the way, of their excellent vision); but in a short time the Europeans also were able to distinguish the white moving figure with the naked eye. The weather was clear, and the distance 14·8 geographical miles. A small object in motion, however, is more easily discerned than if at rest: by the gradual motion of the image over the retina, the impression upon each part continuing for some time, the effect is the same as if a linear image were formed.

Duration of impressions. — A beautiful provision to insure uninterrupted vision, is afforded by the duration of impressions upon the retina, whereby we never lose sight of an object we are viewing, during the necessary winking of the eyelids. M. D'Arcy found that the light of a live coal, moving in a circle, at the distance of 165 feet, maintained its impression upon the retina somewhat more than the seventh part of a second. From the observations of Plateau, it seems that the interval of time, during which the impression retains the same intensity, is more considerable in proportion as the light is moderated; the mean duration of the impression excited by all the colours from the instant of their maximum intensity till their entire disappearance, being one-third of a second in a dark room, and one-sixth of a second in a light room. If two or more impressions succeed each other at such short intervals that the first has not faded away before the next commences, they run one into another, the eye seeming to receive but a single impression; as, for example, the appearance of a circle of fire from a revolving burning stick — when it is in reality the combination of many individual impressions succeeding each other with rapidity: upon this depends many of the most beautiful examples of the pyrotechnic art; from the same cause a flash of lightning appears as a continuous line of light, because the light emitted at any point of the line remains upon the retina until the cause of the light passes over the succeeding points. In order that an object may become visible, it is necessary that the retina should be exposed to its influence for an appreciable time, a fact first pointed out by Lord Bacon, who observes, that notwithstanding the rapidity of the act of vision, a certain time is required for its exercise, which is proved by certain objects, as, for instance, a musket-ball, being invisible on account of the velocity of their motion; for the flight of the ball, he remarks, is too swift to allow an impression of its figure to be conveyed to the sight. This subject has been recently investigated with much success by Mr. William Swan*, who arrives at the following conclusions.

When the eye receives a succession of flashes of equal duration from a light of constant intensity, which succeed each other so rapidly as to produce a uniform impression, the intensity of this aggregate impression will also be constant, provided the number of flashes in a given time varies inversely with the duration of each. The brightness of the impression produced by flashes of light of a given intensity, which succeed each other so rapidly as to produce a uniform impression on the eye, is proportional to the number of flashes in a given time.

When light of a given intensity acts on the eye for a short space of time, the brightness of the luminous impression on the retina is exactly proportional to the time during which the light continues to act. This law has been proved to be true for impressions lasting from $\frac{1}{18432}$ to $\frac{1}{24}$ of a second.

The intensity of the impression produced by light, which acts on the eye for $\frac{1}{100}$ of a second, is almost exactly $\frac{1}{10}$th of the apparent brightness of the light when seen by uninterrupted vision; and the time required for light to produce its full effect on the eye seems to be about $\frac{1}{10}$ of a second. Lights of different intensities produce their complete impressions on the eye in equal times, so that the light of the sun requires the same time as common artificial light to produce its impression on the eye. The brightness of an impression on the eye increases with a rapidity exactly proportional to that of the light by which it is produced.

Rays of different refrangibility act on the eye with equal rapidity. The apparent brightness of the spark produced by electricity of high tension is only about $\frac{1}{100000}$ of what its apparent brightness would become if its duration were prolonged to $\frac{1}{10}$ of a second; and the brightness of electric light increases with the tension of the electricity.

The wonderful rapidity of the electric light is shown by the following experiments: — Viewed by the illumination of an electric spark, the spokes of a wheel in the most rapid rotation appear stationary, vibrating cords seem to be in a state of repose, and a succession of drops, which generally appear to the eye as a connected stream, is seen to be but a succession of drops, because the impression of each image lasts for so short a time that the position of the moving bodies is not altered. The light of electricity of high tension has a less duration than the millionth part of a second.

When on the subject of light, we have alluded to the reproduction of the impression of white light by the rapid revolution of a disk

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corroborates Colonel Smith's results: hence it appears that the liability of brown is $\frac{7+5}{2}=6$, and that red is by far the most fatal colour, green next, then brown, and Austrian grey the least.

* Transactions of the Royal Society of Edinburgh, vol. xvi. p. 581.

painted with the prismatic colours; and Plateau describes an experiment which leads to a singular result. He takes two disks of exactly the same size, made of thick white paper, and divides one into eight equal sectors, of which two and two, corresponding and opposite ones, are coloured red, white, blue, and black. The second disk is coloured entirely black, two sections lying opposite to one another, and rather shorter and narrower than those of the first disk, being cut out. Both disks are then attached to rollers which are as much equal to one another as possible. They are placed vertically behind one another, so that the axes of rotation coincide, and the rollers are set in motion by cords which pass over two wheels, as nearly as possible equal to one another. The posterior coloured disk, which is rendered transparent by varnish, is well lighted from behind by a lamp. On rotation of the disks the whole field at first appears black, but, by gradual transitions, it passes into red, then white, and lastly into blue.

The stimulus of vivid light produces an effect upon the retina which is stronger and lasts longer, in proportion to the intensity of the primitive effect. The after-images of light objects will be light, and those of dark objects dark, if the eye be withdrawn from all subsequent action of light. If, for instance, we look long through a window towards the clear sky, and, turning suddenly away, close the eye, we shall see the light intervening spaces bounded by the dark window frames; but if, on the contrary, the eye be turned towards a white wall, the after-image of the frame will appear light, and the intervening spaces dark. The reason is, that if the eye, already dazzled, be turned towards the white surface, the parts of the retina previously affected by the bright light will be less sensitive to the white light of the wall, than those parts on which the image of the dark window frames has fallen, and which has therefore not been unduly stimulated. If the bright sun, or the intense light resulting from the combustion of lime in oxygen, be gazed upon, the spectrum continues for a long period, and if the eye be closed, it passes through a series of colours until it disappears. The white is followed by yellow, orange, red, green, violet, and finally black, one after the other in regular succession. Sir Isaac Newton experimented upon this subject, and ran a great risk of blinding himself thereby, as is described by him in a letter to John Locke, dated June 30th, 1691. After detailing the various steps of his experiment of gazing on the sun, and observing the subsequent phantasm, he says, — "At length by repeating this, without looking any more on the sun, I made such an impression on my eye, that if I looked upon the clouds, or book, or any bright object, I saw before it a round bright spot like the sun; and, which is still stranger, though I looked upon the sun with my right eye only, and not with my left, yet my fancy began to make an impression upon my left eye as well as upon my right. For if I shut my right eye and looked upon a book or a cloud with my left eye, I could see the spectrum of the same almost as plain as without my right eye if I did but intend my fancy a little while upon it: for at first if I shut my right eye, and looked with my left, the spectrum of the sun did not appear till I intended my fancy upon it; but by repeating this it appeared every time more easily. And now in a few hours' time I had brought my eyes to such a pass, that I could look on no bright object with either eye, but I sâw the sun before me, so that I durst neither write nor read: but to recover the use of my eyes, shut myself up in my chamber made dark for three days together, and used all means to direct my imagination from the sun; for if I thought upon him, I presently saw his picture, though I was in the dark: but by keeping in the dark, and employing my mind upon other things, I began in three or four days to have some use of my eyes again, and by forbearing to look upon bright objects, recovered them pretty well, though not so well but that, for some months after, the spectrum of the sun began to return as often as I began to meditate on the phenomena, even though I lay in bed at midnight with my curtains drawn."

Dimensions of Objects.—With the representation of external things by means of the organ of vision, the mind combines its knowledge of their size and distance. We infer the real magnitude of an object from its apparent magnitude, or from the angle under which its rays intersect each other in the eye; our knowledge of its actual distance from us is merely a deduction of our judgment arrived at through the sensations excited in the eye according to the different positions of objects, and such sensations are regulated by the angle of vision. For instance, we infer the increased distance of an object of known size, as a man, from the decrease of the visual angle. The angle of parallax, or that angle which the axis of the eyes when directed towards an object forms with it at the point of contact, is also to be taken into account, for it becomes greater in proportion to the nearness of the object. We are further aided by the position of the object relatively to other known objects, but here, in forming our conception of true dimensions, we are largely assisted by the lessons of experience. The infant will grasp at the moon; and it is by degrees that it acquires such experience and judgment that the original perceptions of sight become signs of the tangible qualities of external objects, and the distances at which they are placed. In determining the relative distances of objects one to another, we are principally guided by the angle of vision; yet what an exercise of judgment is implied, founded on a comparison of a variety of different circumstances, and involving a complex mental operation, when a magnificent prospect is displayed to our view, and by an instantaneous act of the mind we become aware of the various distances at which all the component parts are placed, the size of each individual part, and the relation held by each to the others. Here however, clearness of atmosphere and a sufficient amount of light are of importance, for every one must be aware how deceptive is the estimate of the size of an object when seen through a fog, or looming large in the gloom of the evening.

Some persons are gifted, as it were, intuitively with the power of judging correctly of the true dimensions of objects. Napoleon possessed this in an eminent degree. He could tell at a glance the number of men composing a distant mass of troops, and the space of ground they would cover when deployed. In doing this a mental computation must have taken place unconsciously, rapid as thought, and based on a combination of great powers of calculation, long experience, and profound knowledge of the subject.

For the production of a distinct image on the retina it is necessary that it be of a certain magnitude, which will depend on the susceptibility of the eye. We may here observe that the *apparent magnitude* of an object must not be confounded with its apparent superficial magnitude, the term being applied to its *linear magnitude*. The apparent superficial magnitude varies in proportion to the squares of the apparent magnitude. The image of an object moderately illuminated must be 0·001 of an inch long, or the extreme rays of light must form an angle of half a minute in the eye at a minimum; whence it follows that an object of mean illuminating power will be visible if its distance is not greater than 68,000 or 69,000 times its greatest length. Strongly luminous bodies, as the fixed stars, are visible at infinitely small visual angles. They excite in the eye merely a sensation of light, without creating any impression as to their apparent magnitude. The disk of the moon subtends a visual angle of half a degree, the diameter of its picture on the retina will be $\frac{1}{230}$ of an inch, and the entire superficial magnitude of the image the $\frac{1}{52900}$th of a square inch; yet forms of light and shade are perceptible whose linear dimensions occupy upon the retina a space whose diameter does not exceed the $\frac{1}{5000000}$ of a square inch. The eye in a healthy condition is capable of reading print in the light of the full moon, and that of the noonday sun, their intensities being to each other as 1 to 300,000. Plateau asserts that white may be distinctly seen in the light of the sun at an angle of 12″, yellow at an angle of 13″, red at 23″, and blue at 26″, but that in ordinary daylight these angles must be half as large again.

In estimating the motions of objects, we are guided by the movement of their images on the retina; and unless a body moves in such a manner that the line of vision shall describe at least one degree in each minute of time, its motion will not be perceptible; for which reason we are not conscious of the movements of the heavenly bodies. The more nearly at right angles to the line of vision the direction of the motion is, the greater will be the apparent motion produced by any real movement of an object.

Erect Vision.—A variety of explanations have been offered to account for objects not being seen reversed, according to the position in which they are depicted on the retina; but it would appear that by many a sufficient distinction has not been drawn between seeing the image and seeing *by means* of it. A little reflection shows that the actual perception of the object takes place in the sensorium, and that the image on the retina is only a necessary step in the process. In truth, we have no notion of upright or inverted, except that which is founded on experience. A man is upright whose head is upwards, and his feet downwards. Whatever be our standard of up or down, the sensible representation of *up* will always be an image moving on the retina towards the lower side, and the sensible representation of *down* will be a motion towards the upper side. The head of the man's image is towards the image of the sky; its feet are towards the image of the ground; and consequently it cannot appear otherwise than upright. So, as all objects are inverted on our retinæ, they do not change their relation one with another, and our only knowledge of position is from relative relation, therefore we may truly say that we do not *see the image on the retina*, but *by means of it*. For every image on the retina, we substitute an object, and seek in a definite direction for the object corresponding to a definite image on the retina. In this we are assisted by other perceptions of sense, there existing the greatest harmony between such perceptions in respect to locality.

Dr. Alison, in an able paper*, advances the opinion, that the harmony between the intimations acquired by sight and by touch, as to the relative position of objects or their parts, notwithstanding that the impressions made by them on the external organs of sight and of touch are arranged inversely in regard to one another, arises from the course of the optic nerves and tractus optici, whereby impressions on the upper part of the retina are in fact impressions of the lower part of the optic lobes—that is to say, of the sensorium—and impressions on the outer part of the retina are, in like manner, on the inner part of the sensorium. This theory was first suggested by Mr. Dick, a veterinary surgeon; but though ingenious, can hardly be considered satisfactory, as it implies the necessity for conditions which cannot always be fulfilled: and truly the question is of a nature not to be decided merely by anatomical inquiry.

Kepler's explanation of objects appearing erect to us is, that the mind, perceiving the impulse of a ray on the lower part of the retina, conceives this ray to be directed from a higher part of the object, and *vice versâ*. Porterfield argues that the mind never sees any picture painted on the retina, and consequently never judges of the object from what it observes in the picture; and that in seeing any

* On Single and Correct Vision, by means of Double and Inverted Images on the Retinæ, Transactions of the Royal Society of Edinburgh, vol. xiii. p. 472.

object the mind, by virtue of a connate immutable law, traces back its own sensation from the sensorium to the retina, and from thence outwards, along right lines drawn perpendicularly from every point of the retina on which any impression is made by the rays forming the picture, towards the object itself, by which means the mind always sees every point of the object, not in the sensorium or retina, but without the eye, in these perpendicular lines. But these lines nearly coincide with the axes of the several pencils of rays that flow to the eye from the several points of the object; and since the mind has also a power of judging rightly of the distance of objects, it follows that every point of the object must appear and be seen in the place where it is, and consequently the object must appear in its true erect position, notwithstanding its picture on the retina is inverted. This theory of lines of visible direction Reid regards as a law of nature, of which our seeing objects erect, from inverted images, is a necessary consequence. Sir David Brewster too believes that erect vision results from the lines of visible direction being in all cases perpendicular to the impressed part of the retina; but Müller offers the following objections:— "The hypothesis that erect vision is the result of our perceiving, not the image on the retina, but the direction of the rays of light which produce it, involves an impossibility, since each point of the image is not formed by rays having one determinate direction, but by an entire cone of rays. And, moreover, vision can consist only in the perception of the state of the retina itself, and not of any thing lying in front of it in the external world. The hypothesis also that the retina has an *outward* action, and that objects are seen in the direction of decussating lines, that is to say, in the direction of the perpendicular of each point of the concavity of the retina, is a perfectly arbitrary assumption; since there is no apparent reason why one direction should have the preference rather than another, and each ultimate sensitive division of the retina, if it had the power of action beyond itself, would act in as many directions, as radii might be drawn from it towards the exterior world."* Notwithstanding these objections, the law of visible direction affords the most satisfactory explanation of the phenonmena of erect vision; all, however, we know positively is, that in the ordinary exercise of vision, the mind infers the positions of objects from an impression made upon the retina, and that it as certainly draws the right conclusion therefrom.

This, however, is not more wonderful than that the undulations of the luminous particles should excite the sensation of light in the retina, or that vibrations acting on the auditory nerve should give rise to sound. We may heap conjecture on conjecture as to the final cause of these phenomena, but we must stop at the limits to the boundaries of human knowledge. The profound resources of the Divine Intelligence excite our wonder and exalt our thoughts, but there are a thousand things abstractedly possible which set at nought our comprehension.

* Elements of Physiology, by Baly, p. 1171.

It is curious that such an acute mind as that of the late eminent metaphysician, Dr. Brown, should have been so satisfied that the perception of the number and position of visible objects is acquired only by association or custom, that he dismissed the subject thus curtly:—"In the single vision of the erect object from a double image of the object inverted, there is nothing at all mysterious to any one who has learnt to consider how much of the visual perception is referable to *association.* If the light reflected from a single object *touched by us* had produced, not two merely, but two thousand, separate images in our eyes, erect or inverted, or in any intermediate degree of inclination, the visual feeling thus excited would still have accompanied the *touch of a single object;* and if only it had accompanied it uniformly, the *single* object would have been suggested by it, precisely in the same manner as it is now suggested by the particular visual feeling that now attends the double inverted image."* It has been justly remarked by Dr. Alison, that if it were only by experience and association with the perceptions of touch that we learned that any object placed before the eyes, and seen by two images, is nevertheless single, we might reasonably conclude that we should never see an object double which we know by touch to be single; whereas we all know, that if by pressure on the ball of one eye, or by any other means we direct the axes of the two eyes to different points in an object, we immediately see it double, and cannot by any means avoid seeing it double so long as that condition of the eyes continues, notwithstanding the full conviction, derived from touch, of its being single. This *tangible* theory (if the expression may be used) has found little favour, but having met with the support of so able a man as Dr. Brown, it could not be passed over in silence.

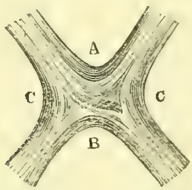
Single Vision.—When both eyes, acting simultaneously, are directed to an object, a single image only is seen. A variety of opinions have existed with reference to this interesting point, some of them sufficiently singular. Gassendi, Du Tour, Porta, and Gall, for instance, asserted that we do not make use of more than one of our eyes at a time, the other being relaxed, and inattentive to objects. Dr. Briggs supposed that single vision was owing to the equal tension of the corresponding parts of the optic nerves, whereby they vibrated in a synchronous manner; and Dr. Reid was of opinion that the correspondence of the two eyes, on which single vision depends, arose from some natural constitution of the eye and mind. Porterfield says that the true cause why objects do not appear double, depends on the faculty we have of seeing things in the place where they are, every point of an object

* Lecture 29.

being seen nearly in a straight line drawn perpendicularly to the retina from that point of it where its image falls and this law of visible direction may be regarded as exercising an important influence on the production of single vision.

In reference to this phenomenon, it is necessary to advert to the remarkable structure of the commissure of the optic nerve. The chiasma results from the junction of the optic tracts, in front of and inferior to the tuber cinereum. The fibres which constitute the inner margin of each tract, B, are continued

Fig. 885.

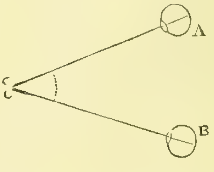


across from one side of the brain to the other, forming no connection with the optic nerves, and existing where those nerves do not exist, as in the mole. These fibres may be considered as commissural between the thalami of opposite sides. The remaining fibres of the tracts go to form the optic nerves, the central passing across to the nerve of the opposite side, and the outermost, C C, passing to the optic nerve of the same side. Besides these, the two retinæ are brought into direct connection by the fibres, A, which form the anterior border of the chiasma. From this arrangement it appears that corresponding parts of the two retinæ are brought into relation one to the other, in the same manner as corresponding parts of the cerebral convolutions are linked together by the various commissures: the right side of each retina appears also to be continuous with the right optic tract, and the left side of each with the left ;thus each side of the central apparatus is brought into communication with its own side of both retinal images, which may be supposed to favour their conception as one.

The learned Arabian Alhazen supposed that when corresponding points of the two retinæ are affected, the mind perceives one image ; this opinion has found favour ; but Dr. Todd and Mr. Bowman, and also Dr. Alison have especially pointed out the importance of the decussation of the commissural fibres. Dr. Alison arrives at the conclusions : first, that certainly in some, and probably in all animals, the structure of the optic nerve brings the impressions which form inverted images on the retina into the same order on the sensorium as those which might result from the touch of the same objects ; secondly, that in those animals which can direct both eyes to one point, the partial decussation of the optic nerves, generally if not universally present, enables the images produced by an object on the corresponding parts of the retinæ of the two eyes to co-operate in producing one impression on the sensorium, and one sensation in the mind; and lastly, that the decussation which takes place in the corpora pyramidalia affords correct information as to objects of sight from impressions made on them simultaneously in both optic lobes, — that is to say, on both sides of the sensorium,— notwithstanding that the impression on each side of the sensorium comes from the opposite side of the object in view. Thus it will be seen that Dr. Alison refers the connection of sight with touch to the decussation of the corpora pyramidalia. We may fairly conclude that there must be some structural provision in the organisation of the cerebral portion of the visual apparatus, which favours the perception of a single image from a double impression, and keeps in perfect harmony the important senses in question: how far the corpora pyramidalia may be concerned, is matter of speculation. The precise action of the mind, by which the single image only is appreciated, is of course unknown to us, but an additional argument in favour of the part performed by the chiasma is afforded by the occurrence of cases where only half an object or word is seen when both eyes are directed to it. Thus, as has been humorously illustrated by Dr. Hull, the word *patriot* becomes *riot;* and of *matrimony*, only *mony* is seen. Such phenomena are (as remarked by Dr. Todd and Mr. Bowman) readily explained by supposing the anatomical arrangement of the sides of the retina, with regard to the optic tracts, to be such as has been described, since any derangement of one optic tract would then affect the same part of both optic images.

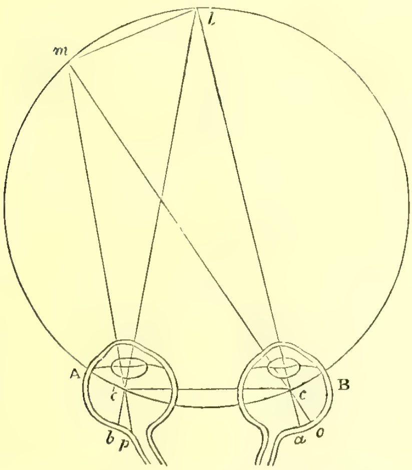
For the production of single vision, it is necessary that the muscles which move both eyes should act in perfect concert. The effect of this is, that the axes of the eyes converge towards the object to which they are adjusted, and the image falls on corre-

Fig. 886.



sponding parts of the two retinæ. Let A B be the two eyes, and C any object before them. Then A C, B C are their axes, which meet in C. An image is consequently produced in each eye which will correspond with the perspective projection of the object from the points A and B. If the two images are unsymmetrically placed, so that the axes meet either before or behind the object, a double sensation is excited, as happens in strabismus, and the double vision of intoxication. The upper sides of both retinæ correspond, as do the lower; and the outer side of each corresponds with the inner side of the other ; but the objects and corresponding points of the retinæ should lie in a certain circle, designated the *horopter;* a circle which passes at once through the point of coincidence, l, of the visual axes, $l\,a$, $l\,b$, and the points of decussation, $c\ c'$, of these axes with the lines of direction.

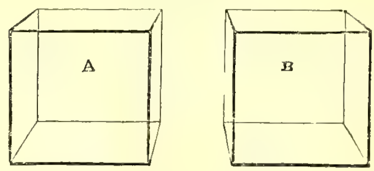
Fig. 887.



Let $c\ c'$ be the centres of the eyes A B, l the point regarded, $l\ c\ c'$ the horopter, a and b the points of the retina on which the axes of the eyes terminate; and let m be a second point in the horopter. The point l appears upon the axial points a and b, the point m at o and p; a line betwixt $l\,m$ will form the chord of the arc of the horopter lying between l and m; and as all triangles drawn upon the arc of a circle have equal peripheral angles, so is the angle $l\ c\ m$ equal to the angle $l\ c'\ m$. Both are farther equal to the opposite angles $o\ c\ a$, $p\ c'\ b$. Moreover $o\ c$ is equal to $p\ c$, and $a\ c$ to $b\ c'$, as radii proceeding from the centres c and c' of the retinal circles, which in each eye have an equal circumference. Consequently o is just as far from the axial point a, as p is from the axial point b; and so identical or corresponding points of the retina are affected by the rays proceeding from both l and m. It is, however, to be borne in mind, that though impressions made on non-corresponding points of the middle portions of the two retinæ are perceived as two, impressions made on non-corresponding points of the circumferential parts are not so perceived, the distance between such points being within certain limits.

When an object is viewed at so great a distance that the optic axes of both eyes are sensibly parallel when directed towards it, the perspective projections of it seen by each eye separately are similar, and the appearance to the two eyes is precisely the same as when the object is seen by one eye only. But this similarity no longer exists when the object is placed so near the eyes that to view it the optic axes must converge: under these conditions a different perspective projection of it is seen by each eye; and these perspectives are more dissimilar as the convergence of the optic axes become sgreater. *Fig.* 888. represents the two perspective projections of a cube. B is that seen by the right eye, and A that presented to the left eye, the figure being supposed to be placed about seven inches immediately before the spectator and viewed with each eye alternately, the other being closed, and the head kept perfectly steady.

Fig. 888.



Mr. Wheatstone has shown that the single sensation excited by these two images is that of a third image different from them both, but excitable only by both of them at once, and attended with the notion of solidity or projection in relief. This he has illustrated by a most ingenious instrument called the stereoscope. Accurate representations are drawn of the appearance presented by an object of three dimensions, when viewed by each eye at a short distance. These drawings are then placed symmetrically in the right and left compartments of a small box, so as to be reflected by sloping mirrors to the eyes of the observer, who must place them as near as possible to these mirrors; then, by moving sliding panels to or from him, he will find a position, and one only, in which the binocular image will be seen single, of its proper magnitude, and without fatigue to the eye, because in this position only the ordinary relation between the magnitude of the pictures on the retina, the inclination of the optic axes, and the adaptation of the eye to distinct vision at different distances, are preserved. It being thus shown that there is an essential difference in the appearance of objects when seen with both eyes, and when only one eye is employed; and that the most vivid belief of the solidity of an object of three dimensions arises from two different perspective projections being simultaneously presented to the mind, the question arises, how is it that persons who see with only one eye form correct notions of solid objects, and never mistake them for pictures? and how happens it that a person having the perfect use of both eyes perceives no difference in objects around him when he shuts one of them? To explain these apparent difficulties, says Mr. Wheatstone, it must be kept in mind that, although the simultaneous vision of two dissimilar pictures suggests the relief of objects in the most vivid manner, yet there are other signs which suggest the same ideas to the mind, and are less liable to lead the judgment astray in proportion to the extent of our previous experience. The vividness of relief arising from the projection of two dissimilar pictures, one on each retina, becomes less and less as the object is seen at a greater distance from the eyes, and entirely ceases when it is so distant that the optic axes are parallel while regarding it. We see, with both eyes, all objects beyond this distance precisely as we see near objects with a single eye; for the pictures on the two retinæ are then exactly similar, and the mind appreciates no difference, whether two identical pictures fall on corresponding parts of the two retinæ, or whether one eye is impressed with only one of these pictures. A person deprived of the sight of one eye sees therefore all external objects, near and remote, as a person with both eyes sees remote objects only: but that vivid effect, arising from the binocular vision of near objects, is not perceived by the former, who, to supply the deficiency, resorts to other means of acquiring more accurate information; and of these the motion of the head is the principal.

Mr. Wheatstone has also shown that, if similar images, differing only in magnitude, are presented to analogous parts of the retinæ, the resultant idea is that of an image apparently intermediate in size between them.*

Foucault and I. Regnault have employed the stereoscope to determine whether complementary retinal images produce the impression of white on corresponding points of both eyes. Two complementary rays, obtained by chromatic polarisation, were thrown in a horizontal direction on the mirrors of a stereoscope, and reflected from them on the screens attached at the sides, so that two small disks of paper were coloured by them. At first one or other complementary colour was alternately seen: after a time, however, the two impressions united to form white; and when the eyes had once become accustomed to this, a whole series of complementary colours could be introduced successively, and nothing but white was seen during the entire experiment.

From the following interesting experiments by Sir David Brewster, it appears that we give solidity and relief to plane figures by a suitable application of colour to parts that are placed at different distances from the eye. If we look with both eyes through a lens about two and a half inches in diameter, at an object having colours of different refrangibilities, as a red rose among green leaves, the two colours will appear at different distances from the eye of the observer. In this experiment we are looking through the margin of two semi-lenses, or virtual prisms, by which the more refrangible rays are more refracted than the less refrangible rays. The doubly coloured object is thus divided into two, as it were, and the distance between the two blue portions is as much greater than the distance between the two red portions (red and blue being supposed to be the colours) as twice the deviation produced by the virtual prism, if we use a large lens or two semi-lenses, or by the real prisms if we use prisms. The images of different colours being thus separated, the eyes unite them, as in the stereoscope, and the red image takes its place nearer the observer than the blue, in the same manner as the two nearest portions of the dissimilar stereoscopic figures stand up in relief at a distance from their more remote portions. The reverse of this will take place, if a concave lens be used, or if the refracting angles of the two prisms be turned inwards. The modified stereoscope has very recently been applied to photographic purposes with the happiest results.

Adaptation to distance. — On no subject connected with the physiology of the eye has there been a greater diversity of opinion than on the mode in which adjustment to distance is performed. That such adjustment is necessary, is proved by the simple experiment of looking between the fingers held about eight inches from the eye, at a distant object. When the distant object is seen distinctly, the fingers will be seen indistinctly; and if we look at the fingers so as to see them quite distinctly, the distant object will be indistinct. Our space will not admit of our doing more than glancing rapidly at the theories which have been advanced, and eagerly supported, to account for this alteration in the focus of the eye. By Bayle, Rohault, Home, Olbers, and Schroeder Vanderkolk, alteration in the form of the eye by means of the external muscles was supposed to be the medium of adjustment. The movements of the iris have had their supporters, of whom the principal were Mile and Pouillet. Ramsden and Sir Everard Home regarded a change in the convexity of the cornea as the medium of adjustment. By John Hunter and Dr. Young (who devoted much time to the inquiry), elongation and shortening of the axis of the lens, through a contractile power inherent in the lens itself, were supposed to be the cause; and lastly, it was referred by many authorities, including Kepler, Scheiner, Camper, and Porterfield, to the movement of the lens by means of the ciliary processes. Porterfield was probably the first who hit upon the true explanation, by referring the adjustment to the action of the ciliary body upon the crystalline, and by distinctly asserting the muscularity of the ciliary body. In reply to the arguments of De la Hire (who maintained that at whatever distance objects were placed, the eyes never altered their focus), Porterfield acutely observes: " This author maintains that it is impossible the crystalline can change its situation, because the ciliary ligament is not muscular, and consequently has no power of contraction: and of this opinion are likewise a great many anatomists, and in particular Hovius: but it appears that all of them have been led into this mistake by an unjust notion they have entertained about the colour of muscles. Every body knows that our muscles are generally of a red colour; but

* Sir David Brewster disputes this and several other deductions of Mr. Wheatstone, in an able paper, "On the Law of Visible Position in Single and Binocular Vision," Transactions of the Royal Society of Edinburgh, vol. xv.

it does not from thence follow that what is not red is not musculous. The muscular fibres of the guts and stomach have scarce anything of redness in their colour; and it is also certain that the pupil does contract and dilate itself according as objects are more or less luminous, and yet none of the fibres which perform that action are in the least red. Whence it follows that the fibres of the *ligamentum ciliare* are not to be deprived of a power of contraction because of a colour different from what generally obtains in other muscles; nor are we to be surprised that so many accurate anatomists, after a careful examination of this process, have not scrupled to affirm it to be truly muscular."

Mons. Pouillet has advanced the hypothesis that, by the peculiar conformation of the lens, near objects are seen through the medium of the rays passing through its centre, and distant objects by means of the circumferential rays. He describes the crystalline lens as made up of strata, differing in curvature and density, so that its section exhibits a series of concentrical ellipses having varying excentricities, the internal strata being more curved and more dense than the external; whence the rays which pass from the latter converge to a more distant point than those from the former. According to this theory, the crystalline lens has many different foci, and the effect should be, that when a pencil of rays falls upon it, those rays which are near the axis of the pencil, and therefore near the centre of the lens, are brought to a shorter focus than those which are near the border; whence near objects would, says M. Pouillet, be seen by means of the central rays, and distant objects by means of those rays which fall near the borders of the crystalline lens.

It has been observed that De la Hire denied that there is an alteration in the focus, whether we look at a near or distant object. He regarded the whole adjustment as a simple enlargement and diminution of the pupil. At first sight this may appear absurd, but there are facts which give some colour to his theory. That a change in the size of the pupil has a considerable influence upon the distinctness of objects at different distances, is known, and if the eye be turned to a near object, as a book, after it has been gazing at a distant ship, the illumination of both being equal, the pupil is observed to contract. Dr. Mackenzie says, it is an error not unfrequently adopted, that if the rays which pass into the eye from a distant object, and those from a near object, have the same divergence, a circumstance which may depend on a mere change in the size of the pupil, they will be collected on the same point of the retina without any change in the refractive media of the eye. That this cannot be the case, is evident from the fact that the rays from a distant object, and those from a near object, although they may have the same divergence, fall on the cornea at different angles of incidence, and must necessarily meet the axis of the eye at different points after refraction. Now the whole effect of the alteration in the size of the pupil is, as explained elsewhere, to increase the distinctness of objects by cutting off those rays which would cause circles of dispersion on the retina. On the one hand, an enlargement of the pupil gives distinctness to distant objects, by allowing a greater quantity of light to enter the eye, and on the other, its contraction assists in rendering near objects distinct by cutting off the lateral rays which are not duly refracted, and would cause confusion of the image on the retina. If, however, a proof were required to show that something more than a mere alteration in the form of the pupil is necessary to the perfection of vision at all distances, it would be afforded by the change termed *presbyopia*. The eye, in what may be called its state of perfect indolent vision, is adapted only to see distant objects, the adjustment to the near focus requiring an effort: the power to make the effort in question is partially or entirely lost by the presbyopic eye, yet the pupil may act as vigorously as ever. Though it is not unusual to find a degree of sluggishness in the actions of the pupil in elderly persons, yet we have repeatedly seen instances in which the iris acted with great vigour, and where a book was obliged to be held at arm's length for the type to be distinctly seen.

Wagner and Dr. Clay Wallace of New York follow Porterfield in attributing the adjustment to the action of the corpus ciliare; the latter considering that, "by the graduating power of the ciliary processes and ciliary muscles, together with the elasticity of the membranes of the vitreous body, the crystalline may be drawn not only backwards and forwards, but its inclination may be changed so as to throw the image on another part of the retina:" and the *modus operandi* he explains by supposing "the outer ciliary muscle to contract the vessels returning from the ciliary processes; the ciliary processes which are attached by the filaments of Ammon to the ciliary zone and crystalline capsule, to become erect and to draw forward the crystalline body; and the inner ciliary muscle, aided by the elasticity of the membranes of the vitreous humour, to draw it backwards."

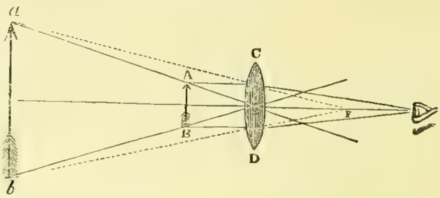
The opinion, however, which appears most satisfactory, is that advanced by Mr. Bowman, who has clearly proved the muscular nature of the ciliary body. "It has (says he) the arrangement of a muscle, very much the structure of a muscle, and is largely supplied with nerves, which are in great part derived from a motor source — the third pair. This muscle arises, or has its most fixed attachment, at the junction of the sclerotica and cornea, as much in front of the lens as is possible, consistently with the preservation of the transparency of the cornea. That it may act more freely, a canal, the *circular sinus*, is interposed between its origin and the portion of the sclerotica which it lies against. Beyond this point it is hardly at all attached to the sclerotica, over which its fibres may be supposed to move in contraction; but it covers, and is inserted into, the anterior one-eighth of an inch of the choroid membrane, which is in this part tougher and firmer than elsewhere, and united in a very special manner to the lens by the ciliary processes, through the medium of a firm tough membrane, and of a strong elastic fibrous membrane proceeding from it to the margin of the lens, and yet not quite to its margin, for an elegant arrangement exists, the canal of Petit, by which traction is made, not on the vitreous around the lens, nor on the edge of the lens itself, so much as on its anterior surface. I confess it seems to me very difficult to doubt that this complicated system of parts is intended to advance the lens towards the cornea, so as to bring forward, up to the retina, the focus of a near object, which would otherwise fall behind the nervous sheet. It is possible also, I think, from the peculiar direction taken by the ciliary muscle, that it may compress the front of the vitreous, and thus help to throw forward the lens." *

An ingenious theory has been suggested by Sturm, and supported by Matteuci, founded on the results of Chossat's measurement of the eye of an ox, to the effect that in place of comparing the optical apparatus of the eye to a system of spherical lenses whose axes are blended, we ought to consider the organ as composed of several refracting media, separated by surfaces which are neither exactly spherical, nor even of revolution or symmetrical about a common axis. Reasoning from this, he argues that a peculiar refraction of the rays of light takes place, whereby tne retina is placed in what he terms a focal interval, which focal interval will change its position according as the external luminous point recedes from, or approaches to, the eye and that the retina will be always met by the concentrated fasciculus around the axis in the focal interval; the surface of intersection of this fasciculus and of the retina being very slightly modified, in order that the impression may not be sensibly altered, or the perception rendered indistinct. This theory is, however, decidedly open to objection, and is rendered unnecessary by that of Mr. Bowman.

Magnifying lens. — It has been already stated that the apparent magnitude of an object depends upon that of the angle of vision under which it is seen, and this increases in proportion as the object is brought nearer to the eye; but the magnitude of the angle of vision being limited, we are obliged to resort to artificial means to enlarge it further than, in its natural condition, is admitted of. The pin-hole aperture affords some assistance, but the convex lens more. The following is the mode in which it acts:—

Let C D be a convex lens, and A B an object lying within the focal length of the glass, then all the rays passing from a point of the object A B will diverge after their passage through the lens, exactly as if they came from the corresponding point of the image *a b*; an eye

Fig. 889.



behind the lens would be able to see the object distinctly through the lens if the image *a b* were at the distance of distinct vision. In this case, however, the object being much nearer the eye, it could not be seen without the lens. The magnifying power of the lens therefore depends essentially on the means it gives us of bringing the object very near the eye, and thus increasing the angle of vision.

Abnormal Vision.

In the consideration of abnormal vision, we propose to divide the subject into

1. Abnormal Vision resulting from defective action of the retina or sensorium; as *Achromatopsy*, *Hyperchromatopsy*, and *Anorthopia*.
2. Abnormal Vision arising from faulty configuration of the eye, or from changes in the refractive media; as *Myopia*, *Presbyopia*, and *Cylindrical Eye*.

Amaurosis, *Chrupsia*, and other morbid conditions, do not fall within the scope of this article.

Achromatopsy (α not, χρῶμα colour, ὤψ the eye), or insensibility of the eye to colours, is an affection which has been recognised nearly two hundred years; but, although cases have been from time to time published in the Philosophical Transactions and other scientific works, our knowledge of the phenomena of this singular condition is of recent date, and is chiefly due to the labours of Wartmann, Seebeck, Szokalski, Purkinje, Himly, &c.

Various names have been proposed for this imperfection of vision; but the majority are exceedingly unmanageable. By Sommer and Szokalski the term *chromato-pseudopsis* has been employed; Goethe proposed to call it *akyano-blepsis*, whilst Purkinje divided the disorder into four varieties,—*achromatopsis*, *chromato-dysopsis*, *akyano-blepsis*, and *anerythro-blepsis*; others again have been satisfied with the simple term *chromato-metablepsis*. Jüngken employs indifferently the denominations of *achromatopsy*, *chromatopseudopsy*, and *chromatometablepsy*. Many writers, however, have adopted the term *Daltonism*, proposed by Prevost, and supported by Wartmann; and, although objectionable as perpetuating the infirmity of an individual, it has the merit of simplicity and easy inflection. The term *achromatopsy* is, perhaps, that most usually employed, although, strictly speaking, it is only applicable to one class. Still, being extensively recognised, we shall adopt it to designate this imperfection of vision; occasion-

* Lectures on the Parts concerned in the Operations on the Eye, p. 60.

ally the expression "Daltonian" may be used for the sake of brevity.

Modifications of insensibility to colours exist in every degree, and in the minor shades are so frequent as to be almost proverbial with reference to the male sex; indeed, if twelve men, taken at random, were shown a number of ribands of the more delicate colours, a diversity of opinion would almost certainly arise as to the appropriate names. The number of persons who cannot distinguish certain colours is considerable; but the defect is seldom known to others, those who are conscious of their imperfection being desirous of concealing it, and some perhaps, not being aware of it till accident leads to its discovery. In every case that has fallen under our notice, there has been reluctance to submit to examination, from the fear of ridicule; and indeed it is difficult to repress a smile when a person is seen to match green and scarlet together, or crimson and dark blue, and earnestly protest that the colours are absolutely identical. The nearest approach to this condition in the healthy eye, and a test by which the embarrasment of Daltonians may be judged of, is the difficulty of distinguishing between blue and green by candlelight; a difficulty which every one must have experienced. Analogous to this defect of the organ of vision, is that better known, because more evident, insensibility of the organ of hearing, whereby many persons are utterly unable to detect the differences between musical notes, or, as pointed out by Dr. Wollaston, their ears may be absolutely insensible to sounds at one extremity of the scale. Sir David Brewster remarks* that, although his own hearing is perfect and each ear equally acute for all ordinary sounds, yet one of them is absolutely deaf to the chirp of the cricket, while the other hears it distinctly. Dr. Pliny Earle has published † a remarkable illustration of the imperfection of the two senses in conjunction. "The whole family (says he) of which the chart has been exhibited, is probably no less generally characterised by a defective musical ear than an imperfect appreciation of colours. Several of the individuals comprised in it are utterly incapable of distinguishing one tune from another. * * A gentleman who has the general defect under discussion, and whose case is included in the thirty-one herein mentioned, is a well-known professor in one of the Metropolitan Medical Schools of the United States. In him the total inability to discriminate between musical sounds is coexistent with the defective perception of colour * * Another of the gentlemen whose case of defective perception of colours is herein noticed, is generally acknowledged as one of the first and greatest of American poets now living. He also is unable to distinguish one tune from another; yet his poetry is not deficient in the requisites of perfect cadence, harmony, and rhythm."

* Philosoph. Mag. vol. xxv. p. 136.

† American Journal of Medical Sciences, vol. 35. p. 347.

It has been remarked by Wartmann as a curious fact, that in no ancient author is there any passage which can be referred to the subject of achromatopsy, and that the numerous travellers who have traversed the old and new world are equally silent in this respect.

As to the relative frequency of achromatopsy, Seebeck states that five out of forty youths who composed the two upper classes in a gymnasium at Berlin, were affected with it, and Prevost has declared that the proportion of this imperfect vision to perfect vision, is as one to twenty. It is true that Chelius and Chevreul entertain a very opposite opinion, but the balance of authority is decidedly against them.

This affection is often hereditary, and is found in some families to a remarkable extent. It sometimes occurs in successive generations, of which a remarkable instance has been published by M. Cunier*, and at other times it appears in alternate generations, descending far more frequently on the maternal side than the paternal. In the case of Mr. Milne, recorded by Dr. Combe†, the maternal grandfather was affected with Daltonism, also his two brothers and a second cousin. In that of a child related by Dr. Nicholl ‡ the maternal grandfather and several of his brothers were similarly affected; such was also the case with two young men mentioned by Dr. Cornaz.§ They were the offspring of the same mother but by different fathers, and in both, achromatopsy existed to a marked degree. But the most striking illustration of the hereditary character of this defect has been recorded by Dr. Pliny Earle ‖, and it is so remarkable that we give it in his own words. "My maternal grandfather and two of his brothers were characterised by it, and among the descendants of the first mentioned, there are *seventeen* persons in whom it is found. I have not been able to extend my inquiries among the collateral branches of the family, but have heard of one individual, a female, in one of them, who was similarly affected.* * * Nothing is known of the first generation (of five) in regard to the power of perception of colours. In the second, of a family consisting of seven brothers and eight sisters, three of the brothers, one of whom, as before mentioned, was the grandfather of the writer, had the defect in question. In the third generation, consisting of the children of the grandfather aforesaid, of three brothers and four sisters, there was no one whose ability to distinguish colours was imperfect. In the fourth generation, the first family includes five brothers and four sisters, of whom two of the former have the defect. In the second family there was but one child, whose vision was normal. In the third there were seven brothers, of whom four had the defect. In the fifth, seven sisters and three brothers, of all of whom the

* Annales d'Oculistique, tom. i. p. 417.

† Transactions of Phrenological Society, p. 222

‡ Med. Chir. Trans. vol. vii. p. 477.

§ Annales d'Oculistique, tom. xxiii. p. 43.

‖ Op. cit. p. 349.

vision is perfect in regard to colour. In the sixth, four brothers and five sisters, of whom two of each sex have the defect. In the seventh, two brothers and three sisters, both of the former having the defect. In the eighth, there was no issue, and in the ninth there a e two sisters, both of them capable of appreciating colours." Of the fifth generation "the defective perception has hitherto been detected in but two of the families. In one of them, consisting of three brothers and three sisters, one of the brothers has the defect, and in the other, a male, an only child, is similarly affected."

Sex exercises a considerable influence on the occurrence of achromatopsy; of the thirty-one cases mentioned by Dr. Earle. twenty-seven were males and four females, and the result of upwards of two hundred cases shows that as a general rule the proportion of males is nine tenths of the whole. A very remarkable instance has however been published by M. Cunier*, where achromatopsy occurred in five generations of one family, there being thirteen cases, and all females; but this stands alone as a notable exception to the general rule. If it be true that the works of the needle are the means of perfecting a delicacy in the judgment of tints, and in women the organ of colour is more developed than in men (as asserted by Gall), these very works ought to lead daily to the detection of achromatopsy if it existed; and we may reasonably conclude that as cases are not discovered they do not exist.

According to the observations of Szokalski, this defect of vision especially obtains among nations having a Germanic origin, as the Germans, English, Swiss and Belgians; the French, Italians, and Spaniards being comparatively free: it seems to be common in the United States, but this does not militate against the proposition, the Americans being descendants of the old British stock. How far this peculiarity may be attributable to the greater sensibility of the inhabitants of southern climes, where the more brilliant sunshine develops colours in a degree unknown in the northern latitudes, is a question which cannot be decided in the present state of our knowledge: nor can we affirm with confidence, as stated by the same writer, that achromatopsy occurs most frequently in robust constitutions, combined with a bilious and melancholic temperament. A difference of opinion exists as to whether achromatopsy is indicated by any visible signs; Szokalski, Ruete, and Himly affirm that there is no diagnostic mark, and Rau considers that a yellowish tinge of the iris, which has been considered by some to be indicative of it, is far too common to be so regarded. Professor Wartmann has in his first memoir drawn attention to a peculiar golden lustre of the eyes, which presents itself in cases of achromatopsy, where the iris is hazel. Miss Sedgwick † says of the historian Sismondi, that he had brilliant hazel eyes; he was a Daltonian. At least five other cases are known to have presented the same peculiarity, but the number is yet too small to admit of this being regarded otherwise than as a coincidence, for in truth there appears to be as many Daltonians with blue, black, and grey eyes, as with hazel, and as many eyes without a yellow pupillary margin as with it.

* Op. cit.

† Letters from Abroad, vol. i. p. 250.

There is sufficient evidence before us to warrant our considering achromatopsy under two distinct forms: *congenital* and *non-congenital*. The former is always persistent: the latter may be divided into *permanent* and *temporary*.

Writers have classified the defect according to degree; but the simplest and most practical arrangement is that of Wartmann, who recognises two classes only: the *Dichromatic* and the *Polychromatic*. This we think advantageous, as avoiding unnecessary sub-classification, the varieties of the defect being endless.

Congenital Achromatopsy. — This form is most common, and the majority of recorded cases of insensibility of the eye to colour are examples of it. It presents the best marked illustrations of both varieties, which we shall proceed to consider.

Class I. (*Dichromatic Daltonism of Wartmann*).— Black, white, and the intermediate shades of grey are the only tints recognized by patients of this class. Such persons distinguish with facility the forms of objects and the gradations of light and shade, but to them all the charms of nature and of art, as expressed by colour, are unknown; their retinæ are rather sensitive than otherwise, and they not only see objects at a great distance, but can read with facility in an obscurity amounting to darkness.

The first of these cases on record was published by Dr. Dawbeny Tubervile, an oculist of Salisbury,* being that of a young woman who consulted him about her sight, which, though excellent in every other respect, incapacitated her from distinguishing any other hues than black and white; it is especially mentioned that she could read "for nearly a quarter of an hour in the greatest darkness." The next, best marked case has been recorded by M. D. Hombres Firmas.† M. ——, of Anduze, of a bilious and melancholic temperament, but leading a very active life, had arrived at an advanced age without its being known, except to a very few individuals, that there was anything uncommon in his sight; but all colours appeared to him as tints of grey, between black and white. Like several others having this infirmity, he was fond of painting, and had painted in his apartment two friezes and a pannel between the windows: of these he was proud; but some of his visitors inquired why he had represented the ground, the trees, houses, and persons all blue? He replied that he wished them to match the furniture, he

* Phil. Trans. No. 164. p. 736. and Lowthorp's Abridgement, vol. iii. part i. p. 40.

† Ann. d'Oculistique, tom. xxii. p. 72.

being quite unconscious that this was red. He had a collection of engravings, some coloured and others plain, but the only difference he could perceive was, that some were clearer than others. When criticising a picture he would discuss the composition of the design, the light, shade, and perspective; but, as to the colours, he was silent. When walking with others in a garden, he affected to speak of the beauty and size of the flowers, their regularity and perfume, but to his eyes they, like the pictures, were all grey. The case of a shoemaker named Harris, described in the Philosophical Transactions,* has been generally quoted as a well-marked example of this form of achromatopsy, but on carefully considering the remarks made upon it by Dr. Dalton †, we are doubtful whether it really was as supposed, and are inclined rather to refer it to the second class.

The case of M. Collardeau ‡ has been described as of this nature. This gentleman was an amateur artist, but the imperfection of his vision gave rise to the strangest productions. So long as he confined himself to the pencil, or to sketching in one colour, he designed with much skill, but his paintings in colours were the reverse of happy. For instance, wishing to work up a scene in which he had drawn a dog, he unfortunately mistook the colour, and painted red all those parts which should have been deep blue. He has been known to confound on the canvass yellow with blue, and red with green, regarding his work with the complaisance of a man who felt that he had achieved success.

The following interesting cases are of a character forming a connecting link between the two classes of achromatopsy. The first is related by D'Hombres Firmas. § Count —— of Alais, aged thirty-eight, married, and the father of a family, possessed excellent vision in every repect, except the perception of colours; but yellow, and the shades between black and white, were the only tints he could recognise. On a number of different roses being placed in his hands, he merely saw that white flowers were brighter than purple; yellow flowers he distinguished, but red, blue, violet, and white blossoms all appeared more or less dark though he distinguished the yellow centres. This gentleman was fond of geology, but found it impossible to judge of the colours which marked various formations in the map of M. Dumas. Lacustrine formations and the lias were the only ones which he distinguished, all the others appearing to him tinted in grey; and he would have confounded them together, if his excellent sight had not enabled him to follow the dotted lines and letters by which they were indicated. He drew with taste in crayon, Indian ink, and sepia; but only on one occasion attempted a scene in colours, of a peasant and a bouquet of flowers. The result was so very unsatisfactory to ordinary eyes, that he was not tempted to repeat the experiment.

The second case has been recorded by Dr. Deconde.* A soldier applying for his discharge on the ground of the formation of cataract, attracted particular attention on account of the cyanic colour of his sclerotica; and on investigating his power of distinguishing colours, it was found that all those of the spectrum were confounded in two fundamental hues, yellow and blue. Dark red, bright red, rose, orange, yellow, green in which yellow predominated, and grey white, all appeared as different shades of yellow: whilst blue, green, and white with a blueish shade, were perceived as blue. All the very deep colours were regarded as black, and all the very light ones had a whitish appearance, though the man did not seem to have cognizance of white, properly so called. Light, decomposed by a prism, appeared to him of uniform blue. His sight was feeble and easily fatigued. Numerous trials always led to the above results.

Class II. *(Polychromatic Daltonism of Wartmann.)*—This form includes the vast majority of cases of insensibility to colours, and presents a very remarkable diversity of phenomena. The colour, which, of all others, is the stumbling-block, is lilac, and next to it rose, indigo, and violet; on the other hand, yellow and blue are most commonly recognised. A very general form is that first described by the illustrious Dalton †, who has given his name to the affection; and the following are the chief features of his case. He was not conscious of any peculiarity of vision until the age of twenty-six, when, a discussion arising as to the colour of the flower of *Geranium zonale*, it was discovered that he and his brother differed materially from other people in their ideas upon the point. About two years afterwards he entered upon an investigation of the subject, and the following are the principal results at which he arrived. The solar spectrum appeared composed of three colours, yellow, blue, and purple, the red being little more than a shade or defect of light. Orange, yellow, and green were shades of yellow, whilst green and blue were strongly contrasted. Of ordinary colours, crimson and dark blue were identical; the colour of a florid complexion being a dull opaque blackish blue, upon a white ground; blood seemed bottle green; the face of a laurel leaf was a good match for a stick of sealing wax; and the back of the leaf answered to the lighter red of wafers. Green baize appeared a dark brownish red; and a light drab was not to be distinguished from a light green; browns were very diversified, some having a great affinity for green, others

* Phil. Trans. vol. lxvii. p. 260.

† Memoirs of the Literary and Philosophical Society of Manchester, vol. v. part i. p. 38.

‡ Observations sur la Physique et l'Histoire Naturelle, vol. xiii. p. 87.

§ Op. cit. p. 73.

* Annales d'Oculistique, tom. xx. p. 52.

‡ Mem. of the Lit. and Phil. Society of Manchester, vol. v. part i.

for red; pink appeared sky blue by daylight, but assumed an orange or yellowish appearance by candle light. Dalton believed that the peculiarity in his vision was caused by the vitreous humour of his eyes having a blue tint: to this point reference will hereafter be made.

According to Professor Wartmann, the following are the most common confusions of colour, ranged in order of their frequency: —

1. Deep red with deep blue.
Indigo with violet.
Deep blue with violet.
Bright orange with bright yellow.
5. Deep brown with deep green.
Dark blue with indigo.
Bright brown with bright green.
Dark red with dark green.
Rose with bright blue.
10. Dark orange with dark yellow.
Bright red with bright green.
Deep yellow with dark green.
Dark brown with black.
Bright red with bright blue.
15. Bright yellow with bright green.
Bright red with bright yellow.
Dark red with black.
Dark red with dark brown.
Dark green with violet.
20. Dark red with dark yellow.
Dark red with violet.
Bright yellow with bright brown.
Bright blue with violet.
25. Dark red with dark grey.
Dark red with indigo.
Rose with violet.
Dark blue with dark grey.
Dark green with indigo.
30. Rose with dark blue.
Rose with indigo.
Dark green with dark grey.
Bright orange with bright green.
White with faint green.

Putting aside the differences in the brilliancy of the tints, it is found that the following numbers express how many times each of those tints is proportionally seen without error.

Red -	- 37	Blue -	- 100
Orange -	- 12	Indigo -	- 0
Yellow -	- 100	Violet -	- 0
Green -	- 59		

Wartmann has given* a very interesting account of his experiments on the vision of Louis D——. This individual did not perceive any great difference between the colour of the leaf and that of the ripe fruit of the cherry; he confounded that of a sea-green paper with the scarlet of a riband placed close to it. The flower of the rose seemed to him greenish blue, and he called the ash colour of quick lime light green. The appearances presented by a solar spectrum were as follows, — the coloured bands, brilliant and distinct, extended a length of about 0·102′. D—— perceived four colours only, blue, green, yellow and red. He limited the blue part exactly to the space occupied by the violet, indigo and blue: he called the green and yellow bands, less an interval of 0·002′ towards the orange, green; he called that band of 0·002′, and a fraction of the red 0·012′ in breadth, yellow; lastly, the remaining 0·008′ of red appeared to him of a red difficult to define. By refracted light the results were nearly the same, thirty-seven plates of glass exhibiting only four different colours in various intensities.

When examined by polarized light, it seems that on the one hand he did not appreciate the equality of intensity of two complementary colours as did ordinary vision; but he found a total and abrupt difference when colours passed at once from the finest red to very rich deep blue, a distinction far from being marked to others.

His visual organ was unable to perceive the different mixtures of red which accompany blue to make it pass into purplish violet. This precise circumscription of the constitutive domain of a colour is a fact which, in the opinion of Professor Wartmann, was new and worthy of being remarked.

Whilst a series of these experiments with polarised light were going on, the sun, which had been obscured, suddenly shone out, and D—— declared that the colours immediately assumed a different tint to his sight, all reddening in a sensible manner, so that he called red that which he had before named green and ill-defined blue, whereas the Professor saw no other change in the colours than an increase of their brilliancy and strength.

Wartmann then submitted the patient to experiments to ascertain his perception of the complementary colours, and the result showed that although his eyes were not insensible to them, the colours which appeared to him complementary were not the same as those so regarded by the normal eye. The Professor then painted a human head, giving to each part a complementary colour. Thus the hair and eyebrows were white, the flesh brownish, the sclerotica black, the lips and cheeks green. When asked what he thought of the head, D—— replied that it appeared to him natural, that the hair was covered with a white cap little marked, and that the carnation of the cheeks was that of a person heated by a long walk.

There are a certain number of cases of insensibility to colours which have been quoted by all writers on the subject. We shall therefore content ourselves with merely referring to them*, describing a few well marked and uncommon instances less generally known.

Dr. Boys de Loury † has published the particulars of a M. H——, who was obliged, on account of his defective sight, to abandon the profession of a dyer. His principal colour was yellow. The brilliant yellow of the apricot and deep brown of the chesnut were only distinguished as varieties of shade. All dark hues were called black; scarlet ap-

* Taylor's Scientific Memoirs, vol. iv. p. 173.

* Cases of achromatopsy are detailed as follows: —Phil. Trans. vol. lxvii. p. 260, vol. lxviii. p. 611; Edinb. Phil. Trans. vol. x. 253; Spurzheim Phrenology, 3d ed. p. 276; Combe's Syst. of Phrenology; Trans. Phren. Society, p. 222; Trans. Med. Chir. Society, vol. vii. p. 477, vol. ix. p. 359; Glasgow Med. Journal, vol. ii. p. 12; Edinb. Phil. Journal, vol. vi. p. 135.

† Revue Médicale, Nov. 1843.

peared as a blue grey, rose colour dirty white; orange, pure yellow; apple green, yellow; lilac, blue; violet, grey. There was no unusual appearance in his eyes, but he saw most perfectly in the evening.

Dr. Sommer * has described his own case thus. Blue can always be distinguished from yellow, bright blue from green, and deep red from black, but green and dark blue are often confounded. Yellow, black, and decided blue are the fundamental colours. If he holds a leaf of a tree and a stick of red sealing-wax side by side he recognises distinctly the difference in intensity between the two colours, but cannot affirm which is green or which red: rather decided blue and rather intense red bear a great resemblance; blue is confounded with red, green with brown, brown and orange with bright brown. As to crimson, lilac, purple and deep scarlet, they are colours of which he cannot form even an idea. He one day met a lady wearing a blue bonnet ornamented with red roses, but could scarcely distinguish any difference between the two. On another occasion when walking out it began to rain. "Then (says he) a crowd of red umbrellas displayed themselves, and I compared the colour to the azure of the sky." The rainbow appeared to him composed of blue and yellow; he knew that there were shades, but could not satisfactorily discern them.

The case of the late Mr. Troughton was examined by Sir John Herschell and Sir D. Brewster, and it was ascertained that he saw the red space yellow; hence according to the views of Sir D. Brewster, he saw a space containing much yellow, and little blue, the red light being as it were absorbed in consequence of the retina being insensible to its action. Sir D. Brewster goes on to say †. "If this be the case there must have been a diminution of light in the red space seen by Mr. Troughton, and I am persuaded from the experiments I made upon his eyes that this was the case; but whether it was to the extent of the total defalcation of the red rays, I will not venture to assert. But it is not necessary that it should be so; the defective perception of red light may be accompanied with a more acute perception of the other colours, in a manner analogous to what takes place in the chemical spectrum, where the removal of the red rays produces an increased action of the rays that are left." Sir D. Brewster, adds that he has long been of opinion that the retina receives a more powerful luminous impression from yellow light than from the pure white light of which this yellow forms but a part.

Persons affected with achromatopsy not only see well in deep gloom, but their vision of distant objects is particularly sharp, from the azure blue of the atmosphere presenting the strongest possible contrast to black. One intelligent person says‡, "So much is this the case with me when viewing a distant object as to overcome the effect of perspective; and the shading in the form and garments of persons at a distance is often so predominant as to overcome the effect of diminution in size; and although, I see the object most distinctly, I am unable to tell whether it be a child near me or a full-grown person at a distance."

Daltonians endeavour to obviate the annoyances arising from their infirmity by taking some standard colours or shades as points of comparison, as for instance the green of grass; they also bring the sense of touch to their assistance, and are enabled by these means, united with close attention, to avoid many errors; but nevertheless they feel repugnance to express an opinion upon colours

Non-congenital Achromatopsy.—This though quite distinct from *Chrupsia*, is generally a morbid symptom, and might easily be confounded with it. It is to be borne in mind that in certain cases of chrupsia objects appear tinged with colours foreign to them; a general officer for instance saw all white objects of a deep orange colour at certain times of the day, and to a lady they appeared of a bright blue *; but in such cases all objects are tinged with a prevailing tint or it is confined to those which are white, coloured objects being properly recognised. In achromatopsy one or more colours are effaced, and the individual is no longer cognizant of them.

Permanent Achromatopsy. — A bootmaker in Paris †, was attacked with amaurotic amblyopia, which followed suppression of the cutaneous exhalation. It was accompanied with rheumatic pains, and there was at first irritation of the retina, but this subsided, leaving the sight imperfect. The patient, however, assured M. Szokalski that he had possessed a full perception of colours until after a copious bleeding from the arm. From that time he could only discern white, black, and grey, and could not distinguish an engraving from a coloured print. He one day bought a piece of yellow morocco leather by mistake for a white piece, and when examined by M. Szokalski, he could not distinguish any coloured patterns which were exhibited to him.

Dr. Mackenzie thus writes: "I always considered this affection as a congenital one, till I was consulted by a man who had gradually become subject to it. He was by trade an ornamental painter, and could judge at one time perfectly of colours. His right eye was affected with mydriasis when he called upon me, and there was incomplete amaurosis of both eyes, so that he could no longer read a common type. On trying him I found he mistook red and green. The use of spirits and tobacco was probably the cause of the affection of sight in this individual."‡

* Graefe und Walthers, Journal für Chirurgie, Bd. v. Heft i. S. 135.

† Phil. Mag. vol. xxv. p. 139.

‡ Glasgow Medical Journal, vol. ii. p. 12.

* Collections from the unpublished medical writings of C. H. Parry, M.D. vol. i.

† Ann. d'Oculistique, tom. iii. p. 200.

‡ Practical Treatise on Diseases of the Eye, 3rd edition, p. 799.

Wartmann* has related a case supposed not to have been congenital; this, however, is uncertain; the particulars are interesting, especially as valuable information, to which we have referred, was obtained from this patient.

M. Louis D —— was the eldest of seven brothers and four sisters, who were assorted in a very singular category. The first set had red hair, and their vision was perfect; the others had fair hair, and all were unable to distinguish colours. Louis D —— belonged to the latter, as regards external appearances, but according to his own recollection, and the evidence of his mother, he perceived colours during his infancy, in the usual manner. At the age of nine years his skull was fractured, after which his perception of colours appears to have become defective. The fact however of his brothers, who resembled him in appearance, being similarly affected from birth, weakens the chain of evidence on this point. His infirmity was for some time unknown, and his father endeavoured, by repeated corporal punishment, to put a stop to what he called a perverse pretence, and a severe correction was administered by his master, a bookbinder, because he used red paper, instead of green, for the covers of some books.

Temporary Achromatopsy. — This form appears to us not to have received the attention it merits, having been passed over in silence, or only cursorily alluded to, by the great majority of writers. The exciting causes are congestion, hepatic derangement, and dyspepsia, and it may exist in conjunction with more or less amaurosis, or by itself, as a simple derangement of vision.

The first case we shall relate is highly interesting from the marked manner in which the insensibility to colours existed, its duration and satisfactory disappearance as restoration to health proceeded. It occurred in the practice of that very able physician, Dr. Hays.†

Mary Bishop, ætat. twenty, was admitted into the Wills Hospital, Feb. 9, 1839. She was of short, robust stature, full habit, very dark complexion, black hair, and hazel irides, flushed face, colour of her cheeks at times almost of a purplish hue; catamenia suppressed. In 1837 and 1838 she had suffered from two attacks of cerebral disease; after the first attack, objects appeared double. The second attack left her entirely blind, in which condition she continued for four months. After this her sight began to return, and at the period of her admission into the hospital, she could read large print. When she came under the notice of Dr. Hays, in May, 1839, she had been largely depleted, and had taken remedies for the restoration of the catamenia, under which treatment her sight had improved. At this time it was discovered that she was unable to distinguish colours, yellow and blue being the only ones she could name with certainty. Nearly all others she termed brown, or hesitated to name, designating however their shades, or intensity of colour accurately. Thus she called a deep red, dark brown; a bright green, light brown; and very pale pink, very light shade of brown. The patient was not sensible at first that she laboured under any particular defect in distinguishing colours. She had noticed, that grass and roses did not appear as formerly, and she remembered that as her sight began to return, the first colour she perceived was yellow. The usual treatment for amenorrhea was adopted, and on the 29th of May the catamenia returned copiously, but continued only for a single day. It was followed, however, by a very marked improvement in vision. Roses now appeared to her of their natural colour, and she could distinguish the difference between the colour of the rose and that of the leaves, which she had not previously been able to do. By the middle of June she was able to see the eye of a needle and the end of a thread, but could not thread the needle from inability to see both at the same time. At this period she was again examined with the prismatic spectrum, and distinguished pretty accurately the yellow, blue, green, and red, but was doubtful as to the orange. On the 30th of November it is stated that her sight was good, notwithstanding another attack of congestion and suppression of the menses. She distinguished all the primitive colours readily, and named most of the secondary ones as correctly as could be expected, with the exception of violet, which she was at a loss to name.

A gentleman, aged 36, librarian to one of our medical colleges, has communicated to me the particulars of his own case in the following words: "A few years ago I noticed that on getting out of bed, and looking at a new carpet which had been laid down but a short time, I was unable to distinguish the colours, though I could clearly make out the pattern, which appeared simply black and white. I felt rather alarmed, and asked my wife if it was the same carpet. She assured me it was, and inquired my reason for putting the question. On telling her, she at once suspected I had taken some bad wine at a public dinner I had attended over-night. I may add that I have invariably experienced the same effects after dining out, more especially if I take more than one kind of wine; and of this I take but little, in consequence of the severe illness I experience on the following morning. If I take grog or punch, the symptoms, including the loss of power of seeing colours, are still more severe."

Simple congestion of the head and eyes, especially when accompanied with fatigue, is also an exciting cause of achromatopsy. Ruete states, that a girl suddenly lost the faculty of distinguishing colours as a consequence of congestion; and we have known instances produced by exhaustion.

A clergyman, 45 years of age, of full habit, but enjoying good health, was performing Divine service in the month of June, 1851, and felt fatigued and oppressed by heat and the

* Op. cit.

† American Journ. of Medical Sciences, vol. xxvi. p. 277.

close atmosphere of the church. At the conclusion of the service, on rising from the kneeling posture, he was alarmed at finding that the crimson velvet cushion and hangings of the pulpit appeared of a dark violet hue, and that other familiar objects which he knew to be red, had likewise changed to bluish green; there was at the same time some giddiness and discomfort in the head. Having rested in the vestry about ten minutes, the symptoms gradually passed away, the crimson objects becoming less and less blue, and the red objects gradually resuming their proper colour. Aperient medicine, &c., was prescribed, and we are not aware of any other attack having been experienced.

Another case occurred during the great Exhibition in Hyde Park. A stout plethoric farmer, aged 52, visited London, and had undergone much fatigue and excitement in seeing the various objects of interest. On the third day, after spending some hours in the exhibition, he felt giddy and oppressed, and remarked that the crimson hangings appeared of a dull brownish green. This led him to notice other objects, and he ascertained that he could no longer discern the difference between reds and greens generally, though yellows and blues retained their proper colour. On his leaving the building, the uniform of the footguards and the colour of the foliage of the trees, nearly assimilated. When he reached home, he slept for three hours; and on awaking, was much relieved at finding that the power of discerning colours had returned.

The extraordinary variety and glare of colours at the exhibition was singularly distressing to the eyes, and numerous persons suffered from congestion of the choroid in consequence.

According to M. Cunier, temporary achromatopsy almost always constitutes one of the symptoms of congestive amblyopia in persons affected with hemorrhoids and venous congestion of the abdomen. The confusion between the sensations of red and blue, takes place every time that the encephalo-ocular turgescence is augmented by the effect of a lively emotion, anger, a rapid walk, too great application of the eyes, &c.* That eminent oculist relates the following case. He was consulted by an officer of artillery, who suffered in a slight degree from congestive amblyopia. Every time that he performed manœuvres, and fatigue increased the cerebro-ocular congestion, the men appeared dressed entirely in blue; the white waistbelts he distinguished, but the red worsted epaulets, the red tuft of the shako, the facings of the coat and red stripes down the trowsers, appeared blue. He could see that the shako and trowsers were of black cloth. A brief repose, with cold water to the eyes and forehead, soon restored natural vision.

An interesting example of temporary achromatopsy, doubtless the effect of congestion, is related by Professor Wartmann. M. Thury, an ex-professor of botany in the academy of Lausanne, had walked during the night from Geneva to Nyon to witness a magnificent aurora borealis, which shone on the night of the 17th and 18th of November, 1848. To his great surprise and disappointment, he could not discern any difference between the blue of the sky and the magnificent blood colour of the aurora, which was viewed with rapture by all around. Singular to say, another lady of Geneva, a septuagenarian, presented precisely the same peculiarity, though both she and the professor had distinctly seen many previous auroras.

The following case, which occurred under our own observation, is an example of temporary achromatopsy caused by vitiated blood circulating through the brain and retina, and disturbing the functions of those organs: —

Mr. H., a solicitor aged 37, of a spare make and melancholic temperament, is frequently subject to attacks of congestion of the liver followed by vomiting and purging of bile. These attacks are ushered in by dull pain in the head and tenderness of the eyeballs, rendering motion of them distressing. At such times he is quite incapable of distinguishing colours, all objects being simply divided into two classes, black and white with their intermediate shades of grey. The vision of objects continues perfectly distinct, but it is not until the portal system has been relieved that the perception of colours is recovered, and then yellow is the first distinguished. If however he takes five grains of calomel, the attack is cut short and the power of discriminating colours at once restored. There is nothing whatever unusual about his eyes, and under ordinary circumstances he possesses perfectly natural vision.

Achromatopsy may be the result of injury, as in the following case related by Dr. Boys de Loury.* An individual was struck by a pistol ball which entered his mouth without touching the tongue and broke through the hard palate and base of the orbit. After his recovery from the wound, the injured eye retained but little sight; only a small spot of the retina was sensible to light, and to use this, the eye was obliged to be thrown considerably to one side. Then objects were seen distinctly but without colour. This person described a palette spread with colours, as a plate with many holes, and confounded the thumb opening with the spots where the colours were placed.

Various explanations, differing widely, have been offered to account for the insensibility of the eyes to colour; and we may remark that the subjects of this affection have in several instances been men of intellectual eminence. As for example, the metaphysician Dugald Stewart, Dr. Dalton the illustrious chemist, Mr. Troughton the eminent optician, Dr. Sommers, Dr. Unzer, of Altona, and Professor Brandis. The opinion

* Op. cit. p. 49.

* Revue Médicale, Nov. 1843.

advanced by Dalton and supported with the ability for which he was remarkable, was this: "It appears therefore almost beyond a doubt that one of the humours of my eye and of the eyes of my fellows, is a *coloured* medium, probably some modification of blue. I suppose it must be the vitreous humour: otherwise I apprehend it might be discovered by inspection, which has not been done."* Before his death, the great chemist had requested his friend Dr. Ransome to examine his eyes after his demise: this was done most carefully, and it was ascertained that though the crystalline lens had the slight yellow tinge common in old persons, the vitreous humour of both eyes was absolutely colourless. Nevertheless the hypothesis has been revived by Dr. Trinchinetti†, who considers that the defect is produced by a *coloration* of one or more of the transparent media of the eye, and probably of the crystalline lens, and even goes so far as to advise depression or extraction of the lens as a means of radical cure!

Goethe‡ attributed the confusion of colours to an insensibility to blue; whereas Szokalski expressly states § that among more than sixty cases of achromatopsy, of which he had notes, there was not one in which there was absolute deficiency of the perception of blue. Others again have supposed that the retina itself has a blueish tinge in such cases, whilst Dr. Thomas Young‖ attributed achromatopsy to the absence or paralysis of those fibres of the retina which are calculated to perceive red.

The able metaphysician Dugald Stewart¶, has viewed the subject from a different point. "In the power (says he) of conceiving colours, too, there are striking differences among individuals. And indeed I am inclined to suspect that in the greater number of instances the supposed defects of sight in this respect ought to be ascribed rather to a defect in the power of conception. One thing is certain, that we often see men who are perfectly sensible of the difference between two colours when they are presented to them, who cannot give names to these colours with confidence when they see them apart, and are perhaps apt to confound the one with the other. Such men, it should seem, feel the sensation of colour like other men when the object is present, but are incapable (probably in consequence of some early habit of inattention) to conceive the sensation distinctly when the object is removed."

This explanation would have weight supposing persons had rare opportunities of contrasting colours, for then their memory might fail them, and they might feel uncertainty as to the proper appellation to be given to a tint; but if there be one sense more than another which enjoys unbounded licence, it is that of sight; not an hour passes that the property of distinguishing colours is not called into exercise, and in this age of high civilisation it is in perpetual activity. Nevertheless Dr. Himly has adopted the same view. It is on record however that intelligent persons have expressly declared that their infirmity arose from no carelessness on their part, as they had made many earnest endeavours to correct it.*

By phrenologists, achromatopsy has been attributed to imperfect development of the organ of colour; Szokalski, though believing that there exists in the brain a portion which presides over the function of vision, and that this portion is diminished in volume in persons affected with achromatopsy, adds, "We know well that phrenologists place the organ of colour in the middle of the superciliary arch; we have, however, examined scrupulously and with great pains many persons who have presented very decided depressions of this arch; but despite of the best wishes in the world, we could never discover in them any trace of chromatopseudopsy."†

Neither does our own experience support the theory of the phrenologists; in two well-marked Daltonians examined by us, the whole superciliary region was remarkably well developed.

The vision of the late Mr. Troughton was carefully investigated by Sir John Herschel, who instituted a series of ingenious experiments for the purpose of ascertaining, if possible, the cause of the imperfection. The result at which he arrived was, "that all the prismatic rays have the power of exciting and affecting the eyes with the sensation of light, and producing distinct vision, so that the defect arises from no insensibility of the retina to rays of any particular refrangibility, nor to any colouring matter in the humours of the eyes preventing certain rays from reaching the retina, but from a defect in the sensorium by which it is rendered incapable of appreciating exactly those differences between rays on which their colour depends.‡

Hartmann§ is of opinion that it is by analysis that we arrive at a knowledge of objects which present themselves to our notice; he supposes that we do not perceive them instantly, but little by little and only by examination of their distance, form and colour, which scrutiny rests on a series of changes operating on the retina, ciliary nerves, and motor ocular nerves: we do not easily recognize objects unless this succession of modifications has become habitual and takes

* Mem. of the Literary and Phil. Soc. of Manchester, p. 43.

† Atti della sesta Riunione degli Scienziati Italiani, p. 712.

‡ Zur Farbenlehre, §§ 111 to 113.

§ Annales d'Oculistique, tom. iii. p. 7.

‖ Phil. Trans. vol. lxxvi. p. 344.

¶ Elements of the Philosophy of the Human Mind, p. 73.

* See Glasgow Medical Journal, vol. ii. p. 17; Op. it. p. 100.

† Op. cit. p. 100.

‡ Encyclopaedia Metropolitana, article "Light."

§ Der Geist des Menschen, S. 152. 1820.

place easily, hence achromatopsy results from a certain state of torpor and indolence of the retina and motor muscles of the eye!

Professor Wartmann, the most recent authority upon this subject, stated in his first Memoir that achromatopsy (or Daltonism) has its origin in a defect of the sensorium. In his second Memoir he enters at length into a somewhat different explanation of the phenomena. "I admit (says he) with Harvey, Young, Jüngken, Müller, and others that its seat is in the retina, and I think that it is produced by an abnormal state of the nervous expansion, in such sort that it reacts equally under two or more differently coloured vibrations. If the vibration caused by a ray of red is identical with that engendered by a green ray, there will be confusion of these colours. This theory is independent of all systems destined to explain light. * * * The theory which explains Daltonism by an abnormal elasticity of the retina has the advantage of substituting a reasonable physical condition for a vague notion of the sensorium: besides, it is supported by facts, because the injuries which alter the ordinary constitution of the visual organ are capable of exciting, permanently or temporarily, a false perception of colours. Lastly it appears to be confirmed by the circumstance that with many Daltonians the eye sees less distinctly the red rays than those of which the refrangibility is greater.*

The actual seat of the phenomena of achromatopsy must, after all, remain matter of speculation, as it is one of those things incapable of demonstration. D'Alembert says: "It is very plain that the word colour does not designate any property of body, but merely a modification of our mind: that, for instance, whiteness and redness exist only in us, and by no means in the bodies to which we refer them by a habit in force from infancy." The knowledge that we possess of the existence of colours is derived from the evidence afforded by the thousands of persons endowed with the power of distinguishing them, and therefore we conclude that they do exist. But supposing we were all like Dalton and many others whose visual organs never appreciate red any more than the generality of eyes distinguish the calorific or actinic rays, we should then not be aware of the existence of the colour called red, which plays so conspicuous a part in the adornment of the universe; or if some few eyes gifted with superior powers discerned it, the majority would have to admit its existence on the evidence of others, not from knowledge derived from their own eyes

As regards remedial measures, Wartmann and Seebeck recommend the employment of coloured glasses of a certain known tint; suppose this tint red, the impression of a green body and of a red body at first the same to the naked eye will be distinguished by the use of the transparent screen. Wartmann, however, admits that this method only remedies mistakes in the specific nature of colours, and not those which apply to the shades of one and the same tint. Jüngken and Chelius have recommended the use of coloured bands, bearing the name of their colour, and Szokalski has suggested that sensations of the various shades may be excited by fixing the eyes on different coloured patterns, and then on a black or white surface. But this proceeding is scarcely so likely to be productive of benefit as that recommended by Professor Wartmann.

Should the achromatopsy result from congestion, such means should be adopted as are best calculated to subdue it; as depletion, purgatives, and low diet. If it arises from menstrual suppression, it will be proper to prescribe emmenagogues, with mustard pediluvia, hip baths, and such other means as are likely to restore the catamenia. Should derangement of the hepatic system be the exciting cause, a dose of calomel, followed by a black draught, will often be sufficient to remove it; but it will be proper to follow such a prescription with alterative doses of mercurials and saline aperients, of which the Pullna and Marienbad waters are very serviceable: taraxacum with or without the nitro-muriatic acid may also be advisable.

Dyspepsia is too protean a disorder for us to attempt more than to suggest the propriety of carefully investigating the particulars of cases where the insensibility to colour can be traced to this cause, and of laying down such a plan of treatment, medical and general, as seems best adapted to the exigencies of each individual case.

Hyperchromatopsy (ὑπὲρ, beyond; χρῶμα, colour; ὄψις, vision). — Our knowledge of this condition of the vision which may be regarded as the opposite to achromatopsy, is at present very limited, and is chiefly derived from the publications of Dr. Sachs * and Dr Cornaz.† As we have never had an opportunity of investigating a case of the sort, we can only draw our information from these and some other sources.

Dr. Sachs is, we believe, an albino, and is in addition affected with hyperchromatopsy. The first account of this very singular anomaly of vision was published by him, and other instances have since been discovered. Professor Wartmann, of Geneva, in a communication with which he recently favoured us, thus writes:—"Quant à l'Hyperchromatopsie, c'est une affection qui n'est probablement pas extrêmement rare. Je connais deux personnes qui m'ont dit en être atteintes, et j'espère être un jour en état de publier quelques recherches sur ce sujet. Cet état n'est point nécessairement lié à l'albinisme."

* Deuxième Mémoire, p. 46. Dr. Wartmann enters at length into the discussion of this subject, but our space will not admit of our extracting his ingenious arguments.

* Historiæ Naturalis duorum Leucæthiopum Particulæ duæ. Erlangen, 1812.

† De l'Hyperchromatopsie, par le Dr. E. Cornaz. Bruxelles, 1851.

The characteristic of Hyperchromatopsy is that of attaching colours not merely to objects which, according to ordinary vision, possess them, but also to other objects which have no pretensions to them, and this to an extent scarcely credible.

It does not appear that the same colours always attach to the same objects with different individuals; on this point there is considerable diversity, but as the account published by Dr. Sachs of his own perceptions is the most minute which has appeared, we shall take it as the ground of the following description:—

The objects to which colours especially connect themselves in this condition of vision are, figures, dates, the days of the week, the letters of the alphabet, and musical notes. These colours are not all equally distinct: the clearest are yellow, different shades of pure white and blueish white; the less clear are orange, red, dull white, dark blue, brown and green. Black only attaches itself to one of the letters of the alphabet. This morbid sensibility to colours thus displays itself:— A and E are red, but the first has more of the vermillion tint, the second most of the rose. I is white, O orange, U black, and is the only example of black; UE or Ü is white, so is M and N. C is of a pale ash colour. D is yellow. F of a dull white. H a blueish ash colour. K approaches deep green. S is of deep blue, and W is brown.

Musical notes indicated by the names of the letters $\underset{\text{Do}}{\text{C}}\ \underset{\text{Re}}{\text{D}}\ \underset{\text{Mi}}{\text{E}}$ et cætera, present generally the same colours as these; however whilst in the alphabet, B and G appear almost colourless, the *Si* flat appears of an ash grey, and the *Sol* of an uncertain green.

Of figures, 0 is almost transparent, of a pale and uncertain yellow, 1 of an undecided white, 2 of an uncertain tint, 3 almost ash coloured, 4 minium red, 5 yellow, 6 indigo, 7 blueish white, 8 brown, 9 almost deep green. The numbers composed of several figures take the colours of the last forming them. 0 does not change the colours of the figures to which it is joined, but gives to them a certain appearance, whilst a figure often repeated in the same number causes the colour proper to it to increase in intensity. 10, 11, 100, 110 and 111 are white; the first of them resembles white glass, the second is milk-colour, the third semi-transparent white; the two last perfect white. 14, 24, 40, 44, 400 and 440 are red, but 15, 25, 50, 55, 500, 555 and 1000 are yellow; why the 1000 is yellow whilst 100 is white we do not understand, as the additional 0 does not account for it

Sunday, is to the eyes of this conscientious observer, white slightly tinged with yellow. *Monday*, another shade of white; the colour of *Tuesday* is obscure and undecided. *Wednesday* is yellow; *Thursday* is of a yellowish green, verging towards orange. *Friday* of a dull white, and *Saturday* is of a blueish ash colour.

It is stated that the abnormal sensations of colour are so intimately connected with these objects, that some can only be seen without them by a strong mental effort, and that in the case of others this does not suffice.

In the present state of our knowledge we are not in a position to offer any satisfactory explanation of this singular anomaly of vision. That its seat is not in the eye but in the sensorium is however most probable, and in this opinion Dr. Wartmann concurs. More extended opportunities for observations will doubtless throw additional light on what must be regarded as a very curious subject.

Anorthopia (ἀ, not; ὀρθὸς, straight; ὄψις, vision).— This is a condition of vision far from uncommon, and is characterised by the individuals subject to it being unable to discern when objects are not parallel one to the other, and is often accompanied by a want of ability to distinguish whether objects are symmetrical. Such persons are incapable of drawing objects correctly; a house will be sketched with its proportions wrong and leaning on one side, and a figure will be equally unnatural, yet the artist wi l be sublimely unconscious of any defects. They are unable to discern whether pictures are straight on the walls, or blinds drawn parallel with the window frame; Negroes are very subject to this peculiarity of vision. Nothing is more common than to see them, when marking out the ground-plan of a house, path, or boundary wall, draw the lines as awry as possible, and yet persist that they are quite straight, nor can they be convinced to the contrary. It has appeared to us that the persons in whom this condition of vision existed in a marked degree, were characterised by unsymmetrical heads and faces, but this may have been a coincidence merely.

In children who show evidences of anorthopia, pains should be taken to overcome it by practice and tuition. They should write upon ruled paper at first, and when subsequently writing on ordinary paper, should always be made to place it straight before them and to write across it by the hand moving on the wrist which should be a fixed point, and seldom moved. In drawing, the correctness of the lines should be ascertained by admeasurement; and the study of geometry, perspective, and all other branches requiring attention to symmetry are calculated to be of service.

Myopia (μύω, I shut; ὤψ, the eye), commonly called *near sight*, is an affection almost, if not entirely, confined to civilization.

Every eye, when in a state of repose, is adapted by its size, figure, and the refractive powers of its media, to the formation of a distinct image of an object presented before it, at one particular distance. This differs in different individuals; but from 12 to 20 inches may be regarded as the distance at which ordinary print is legible, the shortest distance at which it can be seen clearly and without exertion being from 6 to 8 inches. A person who brings small objects nearer to the eyes than 6 inches is considered myopic.

It is commonly supposed that a certain visible conformation of the eye exists in connection with, and characterises myopia; that the eye is full, the cornea prominent, the anterior chamber large, &c.: but this is by no means necessarily the case; for it may happen that of two individuals in whom the apparent configuration of the eyes is the same, one will be myopic, the other presbyopic. It is also a popular belief that near-sight decreases with age; such does not accord with our experience. We have repeatedly seen persons above sixty years of age as near-sighted as in their youth, and are acquainted with a lady of eighty-five, who has certainly never fatigued her eyes with work or reading, and who still uses, and has used for many years, a No. 7. myopic glass.

Myopia may arise from imperfection in the form, consistence, or relation of some of the refractive media; or it may result from the loss of adjusting power. The first description may be induced by too great convexity either of the cornea or lens, or both; by an undue density of any of the refractive media; by a too great distance between the cornea and retina, &c. The effect is always the same, namely, to cause the rays of light to be so much refracted that, in place of being concentrated to a focus exactly on the retina — a point essential to distinct vision — they are brought to a focus before reaching it. It is a law in optics that the nearer an object is brought to the eye, the more divergent are the rays proceeding from it, and consequently the greater the distance at which they will be collected in a focus by refractive media. For this reason it is that near-sighted persons habitually hold objects very close to their eyes, as by that means the image is thrown back upon the retina. One of the causes of imperfect vision in such persons, is the circle of dissipation formed on the retina by the rays after they have crossed at the focal point. This is principally produced by the circumferential rays; and if these can be excluded, vision is rendered much more distinct. Thus it is that great assistance is afforded by looking through a pin-hole in a card, and even by holding to the eye a hollow roll of paper, or the hand partially closed. The habit of half shutting the lids which has given the name to the affection, has reference to the same object — the exclusion of the circumferential rays.

In connection with this point, we may mention that the reason stars are seen earlier in the evening twilight with the assistance of tubes than without, is, as pointed out by Arago, that the tube cuts off a large portion of the disturbing diffused light of the atmospheric strata which intervene between the star and the eye. In like manner a tube is useful even in a dark night in preventing the lateral impression of the faint light which the particles of air receive from all the other stars in the sky, and thereby increases the intensity of the luminous image and the apparent size of the star.

Distant objects appear large to near-sighted persons, because a distinct picture is formed only at the point of intersection of the rays proceeding from an object; as this point falls short of the retina in such persons, the retina receives the rays beyond the point of intersection, and they are consequently more extended. Myopes also read with more ease in partial darkness than those whose sight is perfect. The quantity of rays from an object is always in an inverse ratio to the square of the distance; and as these persons naturally bring the object close to the eye, they receive the full benefit of all the light proceeding from it; whereas other persons are obliged under similar circumstances to close the lids and contract the pupils to see distinctly, whereby much less light enters their eyes than those of myopic individuals; hence they see with greater effort and less distinctness.

In congenital myopia the pupils are frequently large, and do not contract fully. To compensate for this the persons acquire the habit of knitting the brows and half closing the lids, which gives them a characteristic appearance. The handwriting of near-sighted persons is generally small and cramped, the proximity of the letters to the eyes increasng the visual angle subtended by them, thus increasing their apparent size.

Among the exciting causes of acquired myopia are, overwork of the eyes at the focus for near objects, the indiscreet use of glasses, and the necessity of working in obscure light. The first and last may be c'assed together, and apply especially to engravers, watchmakers, jewellers, and other artificers, the nature of whose work requires close inspection. But there is yet another class especially subject to this impairment of vision, namely, literary men. The public are little aware of the extent to which the studious and those who live by the exercise of their intellect, suffer from imperfection of sight. Many instances have fallen under our notice of poor students and writers, whose poverty compelled them to pursue their literary avocations in the gloom of dusky apartments, or by the aid of a dim candle, and who have become myopic and amblyopic in consequence. And scarcely less numerous are those who are visited with this affliction though pursuing their labours under more favourable circumstances. It would appear that even the study of ophthalmic science may cause the same penalty to be paid; for M. Desmarres informs us that one of his pupils became very myopic by exerting his eyes too much in the diagnosis of diseases of the eye; a sad result of most rare industry.

A common cause of myopia is the improper use of eye glasses. In this country they are often worn from affectation; but in France glasses are used by the young men who wish to escape the conscription, for the deliberate purpose of rendering themselves near-sighted, that constituting a ground for exemption During the years 1831, 1832, and 1833, 7·3 per 1000 of the conscripts examined in

France were rejected on the score of short sight.

Oculo-cerebral congestion may give rise to myopia; a case alluded to by Smith was probably of this nature, — that of a person who suddenly became myopic on coming out of a cold bath. And Reviellê-Parise mentions an officer who was similarly attacked at the end of a troublesome ague. Local congestion is said to produce the same effect. Desmarres relates a remarkable instance of a lady excessively presbyopic, who became near-sighted during a severe attack of conjunctivitis, the former condition of vision returning after the attack had subsided. Mr. Tyrrell also mentions a lady who had long suffered from granular lids, which were eventually cured, but she afterwards required the aid of concave glasses, from the cornea having become unusually convex during the continuance of the chronic disease. In each of these cases, there may have been some change, either in the quantity or quality of the aqueous humour, or in the consistence of the cornea.

It is very common to meet with eyes differing in their focal length, and in such cases one usually falls into disuse; it is also occasionally found that one eye will be myopic and the other presbyopic, a condition of vision embarrassing to the patient and the surgeon; but the nature of which may easily be ascertained by careful trial with glasses. Dr. Serre, in a memoir on the application of *phosphenes*, or the luminous spectra excited by compression of the eye *, states that these assist in the diagnosis of myopia. He says that in such cases the nasal and orbital phosphenes appear equal to the temporal in constancy, brilliancy, and sometimes in size; but he cautions us against concluding that the retinæ of myopes are more sensitive than those of persons having normal vision, ascribing the above appearances to the greater prominence of the eyes, which facilitates compression, and admits of its application to the deeper parts of the eye. These results he adds, are at complete variance with the opinion of M. Stœber of Strasburg, who thinks that the proximal cause of myopia may sometimes be a peculiar alteration of the retina admitting of a complication of myopia with amblyopia, or commencing amaurosis; for that if the retina be essentially affected, the orbital, and sometimes the nasal phosphenes are scarcely appreciable, or they may be entirely wanting. Dr. Serre further asserts that which is certainly contrary to received opinions, and (we may add), to our own experience, that when the foci of two myopic eyes differ, the retina of the eye with the shortest focus being that least used, is absolutely stronger and more active than the retina of the other eye.

Myopia may be symptomatic of hydrophthalmia, and of conical cornea. In the former case it will be accompanied with enlargement, and symptoms indicating some inflammation of the eye. In the latter, the change of form in the cornea will be apparent on close examination.* Instances have also come under our notice of congenital cataract having been mistaken for myopia. † In such cases the patients have dull vision, and are unable to see small objects distinctly even with the aid of glasses. On careful examination a greyish hue may be detected in the pupils; and if these be dilated by atropine, the nature of the case is at once displayed by the semi-opaque or slightly turbid lenses becoming visible.

The progress of myopia depends very much upon the line of conduct pursued by the individual. If that be judicious from the commencement, the defect may not increase, or if acquired, may diminish; but its march is too often as follows: — A person who is occupied for months together in reading small type (for example), finds that he discerns distant objects less and less distinctly, and at once jumps to the conclusion that spectacles are required; he goes to an optician, tries a pair, sees better, purchases them, and proceeds with his labour. After a time he finds that these glasses do not afford the same amount of assistance they did at first; they are carefully wiped, but still are not satisfactory, and therefore a pair of a higher power are purchased; with these he sees sharply at first, though they do diminish a little; but they in time are laid aside, and the individual goes on and on, until the whole scale has been run through, and he is half blinded for the remainder of his life. In the progress of such a case other symptoms often develop themselves; not only is the sight rapidly shortened, but it is weakened; the eyes ache, and are speedily fatigued by application; there is oppression about the brow, and often headach; he is teased with muscæ volitantes, and the sight is obscured from time to time by a mist.

The case now assumes the character of impaired vision from overwork, and unless judicious treatment be adopted, amaurosis may be the result.

It is important to know that near sight may be acquired in childhood by the common practice that children have, of approaching their eyes very close to any object on which their attention may be engaged. When learning to read or write, or draw, they almost invariably hold their faces sideways, nearly touching the slate or paper. This should at all times be discouraged. In like manner infants should not have very small toys given them, or such as require to be looked at closely, for not only may they be rendered short-sighted, but strabismus may be caused, for as the visual axes naturally converge when objects are held very near the eyes, the frequent repetition of this may occasion a squint. For the same reason there is sound judgment in printing children's books in good bold type, and it is well to encourage young people to observe distant objects, and to describe what they

* Annales d'Oculistique, tom. xxiv. p. 161.

* See Practical Remarks on Near Sight, pp. 47. 50.

† London Journal of Medicine, vol. i. p. 507.

see in trees, landscapes, the exterior of houses, &c. As a general rule glasses are not admissible for young persons, for if worn there is scarcely any hope of amendment; but it is sometimes necessary to allow them during music lessons, in which case they should be of the lowest power that enables the child to see the notes, and their use should be restricted to that pursuit.

Myopic persons, generally, should remove objects they are regarding as far from them as possible, and should avoid small type, minute writing, and microscopical investigations. The use of a high desk is very important, not merely as tending to prevent oculo-cerebral congestion, but also pain in the chest, which is often caused by stooping; and as a general rule, all near-sighted persons, of whatever age, should exercise the eyes, when in the open air, by endeavouring to make out distant objects.

There is a simple plan which persons who write or read much should adopt as being highly serviceable in preserving the powers of their vision. It is that of raising their eyes from their work at short intervals, and fixing them upon the cornice of the ceiling at the further end of the room, and if there be a pattern, making it out. This exercises the eyes at the focus for distant objects; and, simple as it is, is of great use in preventing nearsight.

There is a form of myopia of which we have seen several examples, and which is deserving of attention. It occurs in young persons, and leads to unmerited punishment. The youth does not hold his book so near the eyes as to attract attention, and reads fluently at perhaps eight or ten inches; but he cannot see objects distinctly at twenty feet. Such young persons have been brought to us under the impression that they were "shamming;" but careful investigation convinced us that such was not the case. Great responsibility attaches to the advice given in a case of this description, as on it depends much of the comfort of the individual during life. He should by no means be allowed glasses, as they would most assuredly confirm the mischief. His books should be of large type; he should frequently rest his eyes when studying; should be much in the open air; and the eyes should be often bathed with cold spring water.

Presbyopia (πρέσβυς, old; ὤψ, the eye) is that condition of vision in which objects are not distinctly perceived unless they are at some distance from the eye. Although not necessarily confined to advanced years, it is one of the changes which warn the individual that the prime of life is past, as it usually commences about the age of forty.

To a person in whom presbyopia is commencing, distant objects appear as clear and sharply defined as ever; but reading, writing, and working, especially by candlelight, become irksome and distressing. The eyes feel strained, and there is uneasiness over the brow sometimes amounting to headach; the page of a book appears misty, the type confused at the ordinary reading distance, and a strong light is indispensable. The person therefore draws the candle to him, and holds the book close to it nearly at arm's length, throwing his head back to increase the distance.

These symptoms are the result of changes in the eye which cause the converging rays of light to be brought to a focus beyond the retina, upon which a confused and imperfect image is consequently depicted. They may be the result either of flattening of the cornea or the crystalline lens, diminution in the density of the humors, or diminished curvature of the retina. Absence of the crystalline lens produces the same effect in an extreme degree.

The explanation of the feelings of discomfort, and other presbyopic symptoms, is simply this—the object being removed to a greater distance than is natural, the visual angle is reduced in size, the picture on the retina diminished, and the quantity of light becomes less: hence the retina, with its somewhat impaired sensibility is unable to appreciate the object without effort, and a considerable increase of light.

The necessity for this increased quantity of light is a frequent cause of amblyopia supervening upon presbyopia, for a very large number of work-people pursue their avocations in densely crowded and ill lighted rooms, and they are obliged to struggle on despite of their failing sight. Dr. Sichel states that one of the causes which renders amblyopia in connection with presbyopia so common in the conciergeries of Paris is, that the majority of persons are tailors and shoemakers, who almost without exception inhabit confined rooms called *loges*, into which light and air can scarcely penetrate. Presbyopia may be congenital, and it is frequently excited in persons under thirty, by the injurious habit of wearing convex glasses, miscalled "preservers." Among the lower and even the middle classes the belief is general that if from any cause the sight is weakened, such glasses are beneficial, an impression most fallacious. It however answers the purpose of some advertising opticians to encourage the idea, regardless of the consequences to their victims.

M. Desmarres states* that country people are almost all attacked with presbyopia at an early age, because their sight is much exercised on distant objects, and very little on near objects, whereas the dwellers in towns are attacked later in life. It may be so in France, but is certainly not the case in England. The same writer affirms that this imperfection in sight is rife in countries where the light is very bright.

The first indications of presbyopia are always perceived in the evening, and it is important that they should be distinctly borne in mind. During the day, persons past the meridian of life, accustomed to read, write, or work can do so without inconvenience, but as

* Traité des Maladies des Yeux, p. 809.

the shades of evening draw in and lights are introduced, they find that they cannot fix their eyes upon their work as before, without fatigue; if they persist, this fatigue increases, and after a time amounts to headach; but if they put on convex glasses of a low power, all discomfort vanishes, and their sight is at once restored, and they can pursue their occupations with perfect ease. If however they persist in abstaining from glasses, and by increasing the light endeavour to improve their sight, the retina will be over stimulated, and in addition to presbyopia, they will acquire dull and imperfect vision of all objects, far as well as near.

There are persons whose sight, never particularly good, but who from easy circumstances have used it little, become alarmed at finding, about the age of fifty, that their eyes appear to have suddenly failed, and they think they are becoming blind. Many such cases have fallen under our observation. The facts are simply these: presbyopia has advanced so slowly and gently, and the eyes have been used so little, that until the defect has become confirmed, the parties are unconscious of its existence. Some accidental circumstance, as an attempt to read a newspaper in the evening, reveals the imperfection: proper glasses are alone required to restore the vision.

Belladonna and atropine produce temporary presbyopia by suspending the power of adjustment, the eye being fixed at the focus for distant objects. Mydriasis also renders the individual more or less presbyopic. Presbyopia may be converted into myopia, and *vice versâ*, of which cases are related by various writers.*

Dr. Sichel has justly pointed out that neuralgia of the eye-ball is by no means infrequent in connection with presbyopia. We have seen several instances, and generally traced it to overstraining the eyes in efforts to read or work without glasses. The pain is at first transient, but if the exciting cause be continued, it becomes more severe and persistent, extending from the eye to the neighbouring parts and not readily yielding to treatment. In such a case, rest to the eyes is all important in the first instance, and suitable glasses are indispensable.

The chief remedial measures for presbyopia are comprised in the early and judicious use of suitable glasses, but the means of prolonging natural sight and of staying the progress of presbyopia are as follows:— Persons habitually engaged in minute work should ascertain by experiment the greatest distance at which they can clearly and without effort see their work, and always endeavour to maintain that distance; they should raise their eyes from time to time, and direct them to some object at the opposite end of the room to alter the focus: but when engaged in lighter pursuits they may if agreeable read at less than their working distance. In reading or writing just that amount and quality of light is proper which thoroughly illuminates the object, and yet feels grateful and pleasant to the eyes. It is injurious to face the light; the best position when reading is with the light rather behind and on one side; the eyes are thus protected from all heat and glare, while the object is fully illuminated. When this arrangement is inconvenient, a screen or shade may be used with advantage. Reading by twilight and firelight is highly injurious to feeble eyes. Stooping over work should be avoided as one great cause of congestion of the eyes; for which reason a high desk is useful. Whenever the eyes feel fatigued, a few minutes' rest and bathing with cold water will be refreshing and beneficial. There are two descriptions of lenses in common use for spectacles, the double concave for short sight, the double convex for long or aged sight; plano-convexes and plano-concaves are scarcely ever employed. It sometimes happens however that the curvatures of the surfaces are unequal; for instance, a ten-inch lens may be required, but the optician may not have what is technically called the "tool" of the proper curve, and therefore selects two tools, the numbers of which combined make ten—as one of seven and the other of three inches—and the lens produced by these, though with surfaces of very unequal curvature, answers the purpose perfectly. *Periscopic* glasses were invented by Dr. Wollaston, but are seldom employed, and there are others with attractive names but not deserving of particular notice.

A common prejudice exists in favour of pebbles, but it is erroneous, for whilst on the one hand their chief merit consists in extreme hardness so that they are not easily scratched, that very hardness renders them difficult to cut and grind, many being broken in the process. They are expensive from this circumstance, and the difficulty of meeting with crystal of sufficent size which is pure and without flaw. Crown glass is now made of such excellent quality and so colourless that lenses made from it possess every qualification that can be desired. Among the many singular things characteristic of the Chinese is their spectacles. Without knowing anything of the theory of the convergence and divergence of light by means of lenses, both convex and concave lenses are used all over the empire, and of such a singular size and shape that there can be little doubt of their being original inventions. They are made of rock crystal ground with the powder of corundum and are of immense size, being retained in their position on the face by means of silken cords with weights attached, which are slung over the ears.

Frames, of whatever material they may be formed (and blue or bronze steel is the best), should possess the following qualifications. The rims should accurately fit the form of the lenses, and be sufficiently strong to retain them; the connecting arch or bridge

* See Practical Remarks on Near Sight, &c. pp. 90—95.

must be of such width and shape that it will fit the nose accurately, and maintain the centre of each glass in front of the axis of the corresponding eye. This is a point of great importance, otherwise the eyes will not have the full assistance of the lenses. The necessity for the bridge being adapted correctly was proved by a case that recently came under our notice, where a wart on the side of the nose had degenerated into a scirrhous growth from the friction of an ill fitting spectacle frame which constantly pressed upon, and irritated that point. The lateral branches of the frame should be sufficiently strong and elastic to retain it in its place, firmly and immoveably under all movements of the head; and they should be of such a shape and size that no undue pressure can be caused on the temples or sides of the head. Besides the injury to the eyes from ill-fitting frames, persons acquire the habit of grimacing in their efforts to see through them. Hand glasses and those retained on the nose by a spring are objectionable; the latter, when clipping the nose, almost invariably throw the centres of the glasses out of the axial lines of the eyes, and both are deficient in that steadiness which is indispensable to perfect and comfortable vision.

The power of bi-convex glasses is indicated by their numbers, and these numbers signify the inches of the focal length.

The numbering of the French glasses, whether presbyopic or myopic, has a much more extensive range than the British, as will be seen by the following lists.

Presbyopic (*French*). 80, 72, 60, 48, 36, 30, 24, 20, 18, 72, 60, 48, 36, 30, 24, 20, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3, $2\frac{1}{2}$, 2, $1\frac{3}{4}$, $1\frac{1}{2}$, 1.

Myopic (*French*). 60, 30, 20, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, $4\frac{1}{2}$, 4, $3\frac{3}{4}$, $3\frac{1}{2}$, 3, $2\frac{3}{4}$, $2\frac{1}{2}$, 2, $1\frac{3}{4}$, $1\frac{1}{2}$, $1\frac{1}{5}$, 1.

Presbyopic (*British*). 48, 36, 30, 24, 20, 18, 14, 12, 10, 9, 8, 7, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{5}{8}$, $2\frac{3}{4}$, $2\frac{5}{8}$, $2\frac{1}{2}$, $2\frac{2}{10}$, 2, $1\frac{3}{4}$, $1\frac{1}{2}$.

Myopic (*British*). 00, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.

The numbers of the double convex glasses below 5 in both scales are confined to patients who have undergone the operation for cataract.

The golden rule in the selection of spectacles, whether for myopia or presbyopia, is to choose the lowest power that is productive of distinct vision; and so long as these afford the necessary assistance the party should rest contented, for if he begins with too high a number or rashly increases the power, it will be found not only difficult to go back, but equally so to subdue the inclination for further increase.

A myopic person should therefore select glasses which will enable him to distinguish the outlines of objects distinctly at about forty-five feet, without diminishing them in the slightest degree; and with these he should be satisfied, not changing them for a higher power unless absolutely obliged.

It frequently happens that the eyes of myopic persons are of different focal length, in which case great care should be taken by diligent trial to determine the powers which will bring the eyes to perfect equality, and with these lenses the frames should be fitted; but there is another condition of vision which is sometimes embarrassing; it is when one eye is myopic and the other presbyopic. This can only be ascertained by careful trial of each eye with convex and concave lenses, and the results are sometimes quite unexpected; if therefore a person using glasses complains of faulty vision with one eye, which cannot be satisfactory accounted for, it is proper to try the eye with a different description of lens, which will frequently show the nature of the case at once. Eyes thus faulty require a double convex and a double concave lens fitted into the same frame, and the same rules apply to their selection, as to glasses generally.

In England the lowest power in use for presbyopia is a glass of 48 inch focus; in France it is otherwise, as will be seen by reference to the table already given. M. Sichel commences with a 72 inch, and in some cases with a 96 inch; Mr. A. Ross, however, who has had an immense amount of experience as an optician, informs us that he has met with but one person who could perceive any sensible difference between these two powers, as far as assistance to the sight was concerned. It is quite possible that in the early stage of presbyopia a 72 inch glass may be sufficient, and if found to be so, it should by all means be preferred to a higher number; but, practically speaking, a 48 inch is that most usually required, because persons in this country seldom seek assistance until the presbyopia has advanced beyond the aid of a 72 inch glass. It has been recommended to calculate the requirements of the eye by the age of the individual, but this is fallacious, as eyes differ much in their natural powers of vision, and not less in the amount of assistance they need. The only true mode of obtaining suitable spectacles is by absolute trial.

Persons should not be satisfied with a hasty trial of glasses in an optician's shop, for the eyes soon become excited and confused, rendering it impossible to arrive at a correct decision. It is far better to select two or three pairs of spectacles which are near the mark, and to test them leisurely at home. Those to be selected should simply give blackness and distinctness to the letters of a book, and enable a person to read or work at the natural distance with perfect comfort; such glasses supply to the eyes precisely that amount of refractive power in which they are deficient.

Cylindrical Eye. — This peculiarity of the organ of vision was first investigated and explained by the present Astronomer Royal. It depends on the curvature of the cornea being greater in the vertical plane than the horizontal, whereby the rays are refracted to a nearer focus in a vertical than in a horizontal plane; this gives rise to much confusion of vision, a point appearing a line, a circle an oval, and a square a parallelogram. In an interesting case related by Dr. Robert Hamilton*, the patient, when looking at a clock, was unable to distinguish the hands if they pointed perpendicularly, as at six o'clock, but if horizontally he had no difficulty: so when looking at a wheel at a little distance, the horizontal spokes only could be seen. The patient was a coach painter by trade, and this peculiarity of vision greatly interfered with his business, for he could not draw vertical lines with any degree of correctness, and unwittingly made them slanting, a serious fault in heraldic devices; horizontal lines he drew with perfect precision. His method of correcting the perceptions of perpendicular lines was to bend his head at right angles with his body, whereupon upright bodies became distinct and accurately represented. This man also practised a manœuvre which forcibly reminds us of an act common to persons having conical corneæ, that of placing the fore-finger at the outer angle of the eyelids and drawing them outwards whereby vision is improved.

To remedy the defect under which he laboured, Professor Airey made a pin-hole in a blackened card, which he caused to slide on a graduated scale; then strongly illuminating a sheet of paper and holding the card between it and the eye, he had a lucid point on which he could make observations with ease and exactness. Then resting the end of the scale on the cheek bone he found that the point at the distance of 6 inches appeared a very well-defined line inclined to the vertical about 35° and subtending an angle of 2°. Again, at the distance of $3\frac{1}{2}$ inches, it appeared a well-defined line at right angles with the former, and of the same apparent length. It was therefore necessary to make a lens which, when the parallel rays were incident, should cause them to diverge in one plane from the distance of $3\frac{1}{2}$ and in the other plane from the distance of 6 inches. The professor obtained a lens of which the radius of the spherical surface was $3\frac{1}{3}$ inches, of the cylindrical $4\frac{1}{2}$ inches, and with this he was able to read the smallest print.

In Dr. Hamilton's patient the relation of the horizontal to the vertical focus appeared to be as $5\frac{1}{2}$ inches to $6\frac{1}{2}$ inches, and on trying him with plano-concave cylindrical lenses, it was found that a lens of 24 inches focal length, the cylindrical surface being made to act horizontally, operated very beneficially. Besides this irregular refraction the man was myopic, but the lenses in question fitted as spectacles, enabled him to see well.

The defect of the cylindrical eye may be detected by making a small pinhole in a card which is to be moved from close to the eye to arm's length, the eye meanwhile being directed to the sky, or any bright object of sufficient size. With ordinary eyes the indistinct image of the hole remains circular at all distances, but to an eye having this peculiar defect it becomes elongated, and when the card is at a certain distance passes into a straight line. On further removing the card the image becomes elongated in the perpendicular direction, and finally if the eye be not too long-sighted, passes into a straight line perpendicular to the former.

Professor Stokes has invented a highly ingenious instrument for determining the nature of the required lens, and the following is the proposition on which it is based.

Conceive a lens ground with two cylindrical surfaces of equal radius, one concave and the other convex, with their axes crossed at right angles; call such a lens an *astigmatic* lens: let the reciprocal of its focal length in one of the principal planes be called its *power*, and a line parallel to the axis of the convex surface its *astigmatic axis*. Then if two thin astigmatic lenses be combined with their axes inclined at any angle, they will be equivalent to a third astigmatic lens determined by the following construction.

From any point draw two straight lines representing in magnitude the powers of the respective lenses, and inclined to a fixed line drawn arbitrarily in a direction perpendicular to the axis of vision at angles equal to twice the inclinations of their astigmatic axes, and complete the parallelogram. Then the two lenses will be equivalent to a single astigmatic lens represented by the diagonal of the parallelogram in the same way in which the single lenses are represented by the sides. A plano-cylindrical or spherico-cylindrical lens is equivalent to a common lens, the power of which is equal to the semi-sum of the reciprocals of the focal lengths in the two principal planes, combined with an astigmatic lens, the power of which is equal to their semi-difference. If two plano-cylindrical lenses of equal radius, one concave and the other convex, be fixed one in the lid and the other in the body of a small round wooden box, with a hole in the top and bottom, so as to be as nearly as possible in contact, the lenses will neutralise each other when the axes of the surfaces are parallel; and by merely turning the lid round, an astigmatic lens may be formed of a power varying continuously from zero to twice the astigmatic power of either lens. When a person who has the defect in question has turned the lid till the power suits his eye, an extremely simple numerical calculation, the data of which are furnished by the chord of double the angle through which the lid has been turned, enables him to calculate the curvature of the cylindrical surface of a lens for a pair of spectacles which will correct the defect in his eye.*

A curious case is related in the Annales d'Oculistique †, of an anomaly of vision, which was probably the consequence of a defect in the form of the cornea, such as that under consideration. M. Schnyder, the Pastor of Menzberg in the Canton of Lucerne,

* Monthly Journal of Medical Science, June 1847.

* Report of the British Association, vol. xviii.

† Tom. xxi. p. 222.

was presbyopic for horizontal lines and myopic for vertical. This he remedied by wearing spectacles the glasses of which were cylindric bi-convexes, with rectilinear, horizontal and similar axes. These glasses obviated the presbyopia relative to the horizontal lines, and they were combined with sphero-biconcave lenses to get rid of the myopia for vertical lines. Each of the glasses was made moveable for facility of cleaning.

The following means are recommended to ascertain if an eye has the defect now described. The person should attentively contemplate for some time and with attention a cross, three or four lines in size, made of fine wire and fixed in a frame. If affected, he will see the horizontal lines differ in thickness and blackness of tint from the vertical.

To determine the focal length which the lenses should have, a person whose sight is presbyopic in one direction should take bi-sphero-convex lenses which enable him to see distinctly at the ordinary distance the lines which otherwise appear indistinct: he can deduce the focal distance of the cylindrico-convex glasses. A person myopic in one direction should do the same with regard to bi-sphero-concave lenses. The convex glasses should be chosen of one or two numbers stronger.

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(The subject of Vision is more or less treated of in works on Optics and Natural Philosophy; papers on its physiology and pathology are very numerous, and are to be found in Philosophical Transactions and Journals, in the Annales d'Oculistique, &c.)

(*W. White Cooper.*)

VITAL STATISTICS.—The duration of human life, with a consideration of the principal causes by which it may be lengthened or curtailed, is a subject which evidently belongs both to the domain of physiology and to that of statistics. It belongs to physiology, inasmuch as the duration of human life is the final effect of the operation of natural causes brought to bear on the healthy human frame; and it belongs to statistics, whether we use that term in the less exact sense of a branch of human knowledge largely indebted to the use of numbers, or in the more accurate sense of a department of science, having an important bearing on the interests of the public.*

In this place it is proposed to take only a limited view of the subject of Vital Statistics, and to examine the scientific methods which have been suggested and employed for determining the true duration of human life in communities and classes of men; in other

* For some remarks on the true meaning of the term "Statistics," see STATISTICS, MEDICAL, note, p. 803.

words, to do for this important branch of statistics what has been done elsewhere for the statistical or numerical method.* Having already insisted on the precautions to be observed in the use of numbers as a scientific instrument, it remains to determine the precise value of those measures of the duration of life which are in common use for scientific and practical purposes.

On a superficial view of the subject, it might seem sufficient, in order to determine the mean age attained by a given class of persons exposed to a given class of influences, to collect the ages, at death, of a certain number of persons belonging to that class, to add those ages together, and to divide the sum by the number of persons. But it must be evident, on further consideration, that an average so obtained may furnish a very imperfect measure of the longevity of the class, and of the force of the influences brought to bear upon the individuals of whom it is composed.

In order to build up a science of Vital Statistics — in other words, in order to determine the true influence of external agents on the duration of human life, we must make use of such materials as happen to be ready to our hands. These materials do not always present themselves in the same shape, nor do they all possess the same value. Sometimes they are simple averages; at other times they are complex calculations based upon the same, or similar facts, but moulded into new forms by means of certain necessary corrections. A few preliminary observations on these materials will be found to answer several useful purposes. They will serve, at one and the same time, as a test of the value of the principles sought to be established, and as a check to the tendency with which the statist is often reproached to exaggerate the value of inferences drawn from numerical data.

Several methods are in use for measuring the duration of human life. Of these, the best known and most commonly employed are the following: —

1. The mean age at death; 2. The rate of mortality; 3. The expectation of life; 4. The mean duration of life; and 5. The probable duration of life. Other terms, such as the specific intensity of life, and other methods, such as the ages of the living, are occasionally employed.

1. *The mean age at death.* — The mean, or average age at death, is the sum of the ages at death, divided by the number of deaths. Thus, if five persons die at the respective ages of 20, 30, 40, 50, and 60, their mean, or average age at death is $\frac{20+30+40+50+60}{5}$, or 40 years; and if a second group of five persons die at the respective ages of 20, 35, 50, 65, and 80, their mean age at death is $\frac{20+35+50+65+80}{5}$, or 50 years. Now, if these two groups of five persons were each exposed during their lives to a peculiar set of influences, the mean age which they respectively attained would be a measure of the force of those influences. But such a measure would be open to the serious objection that the number of facts from which the averages are calculated is insufficient. Let us, however, suppose this objection to be set aside by increasing the number of deaths in each case to several hundreds or thousands, so as to embrace either the entire number of deaths of the classes submitted to comparison, or such a considerable proportion of deaths taken without selection as would give satisfactory results in accordance with the strictest requirements of the numerical method, the question still presents itself, Is the mean age at death a safe measure and standard of comparison? The answer to this question must be in the negative. The mean age at death is not always a safe and sound standard. Its employment would often lead to very erroneous inferences. It will therefore be necessary to discriminate between those cases in which it may be employed with safety, and those in which its use would lead to fallacious results.

The mean age at death can be employed with safety as a true test or measure only in those cases in which the calculation purporting to embrace an entire class of persons, every member of that class is included, or in which the calculations embracing only a section of an entire class, the class in question is retained in a state of perfect uniformity during the whole time comprised in the calculation. According to the first supposition, we take a given number (say 100,000) of children born in a given year, and trace them through life till they are all dead, summing up their ages at death, and dividing by the number of deaths. According to the second supposition, we extract from some register of deaths the ages of all who die during some term of years, having ascertained, by referring to the census, that the population has continued stationary (that is to say, constantly gaining as many by fresh births as it loses by death), during the time over which the calculations extend. The same reasoning will be found to apply to the mean age at death, taken as a measure of the true duration of life of the members of any handicraft, trade, or profession. It can only be a true measure so long as the blanks caused by death are filled by new recruits, entering at the same age as the age of entrance of the deceased. In all other cases but those now specified, the mean age at death is a more or less fallacious measure of the true duration of life.

As the mean age at death has been lately revived as a measure of the duration of human life, and a test of the sanitary condition of the population, though its fallaciousness was long since recognised and pointed out by the early constructors of life-tables, it may be well to devote some space to a statement of the cases in which the proposed test is most open to objection.

a. The mean age at death has been employed as a test of the sanitary condition of a nation,

* See STATISTICS, MEDICAL, p. 801.

and as a measure of that condition when compared with another nation, or with the same nation at another time, in ignorance or forgetfulness of the well-ascertained fact that the living population of one nation may differ very widely in its composition from the living population of another, and that the elements of the population of the same nation may undergo very extensive changes even in a short term of years.

In illustration of the first of these statements, it will suffice to instance the strongly-contrasted populations of England and America, of which the first has 46 and the second 54 in the hundred under 20 years of age, the number above 20 being, of course, reversed. In the two populations of Denmark and Sardinia, on the other hand, the relative proportions at different ages are very nearly the same; and, when expressed in round numbers, for long intervals of age, identical. As a general rule, however, there is considerable difference between one population and another in the proportion of persons living at the same ages. In support of the second of these statements, the change which took place in the population of England in the interval from 1821 to 1841 may be adduced. At the former period, the persons living under 20 years of age were 49 per cent. of the whole population, but in 1841 they had fallen to 46 per cent.

There is no room for doubt, therefore, that different populations vary in their composition, and that the same population may, in course of time, undergo considerable changes, and exhibit very striking contrasts in the number of persons living at different ages.

Such being the case, it will not be difficult to prove that the differences in question do so materially affect the mean age at death as to rob it of its alleged value as a test or measure of the sanitary condition of nations. We have only to suppose the young population of America transferred to England, and exposed to the same causes of death as determine the duration of life of its own inhabitants, in order to be fully convinced of the fallaciousness of this test. Now, according to the rate of mortality prevailing in England, little more than half its inhabitants die before completing their 20th year, and somewhat less than half after that age. If the mean age of all who die under 20 years of age be taken at 5 years, and of all who die above 20 at 60 years, the mean age at death of fifty persons dying out of the respective populations of England and America, will be about 34 and 30 years. These numbers, however, though correctly calculated from the rough data just assumed, diverge much less widely than the true results, for the actual mean age at death, which is 29 years in England, is only 20 years in America.* So that two populations, subject to the same law of mortality, and losing the same number of persons at the same ages, in consequence of the different constitution of their respective populations, may have a widely different mean age at death. Similar results to those obtained by comparing England and America are arrived at if we compare England in 1821 with England in 1841. The mean age at death, which in 1821 was 25 years, became in 1841, owing to the change in the population already referred to, 29 years.* If any further illustration of the fallacy of the mean age at death, when used as a test of the sanitary state of nations, were required, it might be found in its failure when applied to countries of which the true position in the sanitary scale has been ascertained by the application of unexceptionable tests. The three nations, England, France, and Sweden, for example, occupy the following relative position:—

1. England. 2. France. 3. Sweden.

But if the mean age at death were taken as our guide, they would rank as follows:—

1. France. 2. Sweden. 3. England.

The mean age at death being 34 for France, 31 for Sweden, and only 29 for England. †

b. The mean age at death has been employed as a measure of the relative sanitary condition of English counties, cities, and towns, of town and country, and of the several districts of large cities. To show the fallacy of the method as so applied, it will suffice to prove that the populations thus compared are composed of different elements. Taking, as before, the number living below 20 years of age as an illustration, it appears that while there are 47 in the hundred under 20 in Essex and Suffolk, there are only 44 in the hundred under 20 in Staffordshire; that for 47 in the hundred in Leeds, 46 in Sheffield and Birmingham, and 44 in Manchester, there are only 42 in Liverpool, 41 in Exeter, and 40 in London; and, lastly, that the population under 20 years of age, which amounts to 47 per cent. in Bethnal Green falls as low as 41 in Clerkenwell, 40 in Kensington, 36 in St. Giles's and Marylebone, and 31 in St. George's, Hanover Square. The effect of this variable distribution of the population on the mean age at death is very well marked, and is placed in a very striking light by supposing the population of the metropolis to be transferred to some of these counties and cities, and to be exposed to the influences for good or evil which are brought to bear on the duration of life of their actual populations. Thus, if the population of London, of which 40 per cent. are under 20 years of age, were to be transferred to the county of Hereford,

* See an essay by F. G. P. Neison, Esq. in the 7th volume of the Journal of the Statistical Society.

The exact age, deduced from the rough data assumed in the text, will be as follows:—

England, $\frac{46}{2} \times 5 + \frac{54}{2} \times 60 = 115 + 1620 = 1735$, which, divided by 50, gives 34·7 as the average age.

America, $\frac{54}{2} \times 5 + \frac{46}{2} \times 60 = 135 + 1380 = 1515$, which, divided by 50, gives 30·3 as the average age.

* For the facts on which these comparisons are founded, see an essay in the 6th vol. of the Journal of the Statistical Society. By G. R. Porter, Esq.

† See the 6th annual Report of the Registrar General, p. 572.

where the average age at death is nearly $38\frac{1}{2}$ years, the mean age at death would become $30\frac{1}{2}$ years, or a year and a half in excess of the mean age at death of the existing inhabitants of London. The advantage, therefore, which the county of Hereford enjoys over the metropolis, in a sanitary point of view, instead of being represented by the difference between 38¹ and 29 years, or $9\frac{1}{2}$ years, is really not more than a year and a half. Again, the average age at death in the metropolis is 29 years, and in Sheffield 23 years; but if the population of the metropolis were transferred to Sheffield, the average age at death would be 28 years. So that the difference of 6 years, which, according to this test of the mean age at death, marks the sanitary superiority of London over Sheffield, dwindles, under this very obvious correction, to one year. If we apply the same correction to the several districts of the metropolis, we obtain similar results. Bethnal Green is the district in which the mean age at death is lowest, while in Kensington it attains its maximum. In Bethnal Green the mean age at death is 26, in Kensington 32. But the population of Bethnal Green transferred to Kensington, would have a mean age at death of 27 years; so that in this case also a difference of six years in favour of the more aristocratic quarter dwindles down to one year. In some cases the use of this corrective actually reverses the position of the two populations submitted to comparison. Thus, the mean age at death in the united parishes of St. Giles's and St. George's Bloomsbury is 28 years, and in Bethnal Green, as has just been stated, 26; but transfer the population of Bethnal Green to St. Giles's, and the mean age at death becomes 24 years. The application, therefore, of this correction completely alters the relative position of the two parishes, so that the parish which, when tested by the mean age at death, seemed the healthiest, proves to be the most unhealthy. Serious errors and exaggerations have also been committed in comparing the smaller districts of our large towns with each other. The meanest and most squalid districts are as naturally the resort of those who marry early, and of those who are sunk into poverty by the burden of large families of young children, as better districts are the abodes of the more prudent and least encumbered members of society. The lowest districts of the large towns of England are also the resort of that part of our population which indulges most habitually in intemperance, and in all the habits that engender poverty, misery, and disease. It is, therefore, inevitable that in comparing the worst districts with those of a somewhat better class, we should be comparing populations containing a large proportion of persons liable to a high mortality for reasons other than the insalubrity of the districts themselves with those containing a smaller proportion.

c. The mean age at death has also been used to test the sanitary condition of different classes of persons inhabiting the same town or town district. A very extensive series of tables, for instance, has been compiled, in which the mean age at death of the gentry, tradesmen, artisans, and paupers of the several parishes of the metropolis is represented, and used as a measure of their sanitary condition.* The parish of St. James's, Westminster, in which the class termed gentry is more likely to be appropriately named than in the poorer and less fashionable parishes, may be conveniently taken as an example. In this parish the average age at death, children included, is 42 for gentry, 26 for tradesmen, 21 for artisans, &c., and 49 for paupers. The differences are here so extraordinary, as only to admit of explanation on the supposition of a vast disproportion between the numbers living at the same ages in the several classes. If the element of age in the living is disregarded in comparing the gentry with the artisans out of the workhouse, it must equally be disregarded in contrasting the gentry with the paupers in the workhouse, who are drawn chiefly from the artisan class. The difference between 49 (the mean age at death of paupers), and 42 (the mean age at death of the gentry) is obviously due to the greater average age of the inmates of the workhouse, as the difference between 42 (the mean age at death of the gentry), and 21 (the mean age at death of artisans), is traceable mainly, if not wholly, to the great disparity in the ages of the living members of the two classes. Unfortunately we are not yet in a condition to apply to the mean age at death of these classes of the population, the same correction which, when applied to counties, cities, and city districts, served in so striking a manner to equalize the results. The ages of the living members of the several classes of society is still an important desideratum. The tables under consideration also give the mean age at death of gentry, tradesmen, artisans, and paupers dying after 21 years of age. In the parish of St. James's, Westminster, the mean ages at death of these classes are 57, 51, 46, and 58 respectively. The differences, though less considerable, are still at total variance with the results of the most accurate inquiries into the value of life of the same classes of society †, and only admit of explanation by supposing a great disparity in the ages of their living members, together with an erroneous method of selection and classification.

d. The mean age at death has also been employed to test the sanitary state of different

* These Tables are published in the same volume (vol. vii.) of the Journal of the Statistical Society, which contains Mr. Neison's valuable essay just quoted. They form part of a paper by Mr. Chadwick, "On the best Modes of representing accurately by Statistical Returns the Duration of Life, and the Pressure and Progress of the Causes of Mortality among different Classes of the Community, and amongst the Populations of different Districts and Countries."

† See especially, Contributions to Vital Statistics, by F. G. P. Neison, in which the artisan class is shown to occupy a much more favourable position in the sanitary scale, than had previously been supposed.

classes of society, and of the members of different professions, without reference to their place of residence. But little objection can be made to this test when applied with ordinary precaution. If the earliest age admitted into the tabular abstracts, from which the averages are calculated, is the same in all the classes submitted to comparison; if during the time over which the observations extend the classes compared with each other have received no rapid accession of numbers; and if the deaths are those of the whole body of the profession or trade (or, if of a section only, then of a similar section in every case), the mean age at death will constitute a fair measure of the relative sanitary condition of the several classes in question. But if, on the other hand, two professions or occupations are compared, in which the age at entry is not the same; or the one is stationary in point of numbers, while the other is rapidly increasing; or if the whole body is taken in the one case, and only the senior or junior members in the other, the results will be quite unworthy of confidence.

Some of the greatest misapprehensions existing with respect to the duration of life of certain classes of the community, are traceable to the selection of the senior members of a class to represent the entire class to which they belong. Nothing is more common, for instance, than to hear royal families, or the members of the aristocracy, or the clergy, or the army, spoken of as long-lived, on the strength of the advanced ages attained by kings, peers, archbishops, or general officers. In making a selection of the more conspicuous members of the class, the significant fact is overlooked that they are also the oldest members, and that they do not attain their exalted rank till a period of life greatly in advance of that at which they entered their several professions. The mean age, at death, for example, of archbishops and bishops of the established church, is upwards of 71 years, but the mean age at death of the whole body of the clergy is about 64 years. A similar disparity would be found to exist between the peers and the whole body of the aristocracy, and between general officers in the army, and admirals in the navy, and the whole body of officers in the two branches of the public service.

The tables already referred to as comparing the four classes of gentry, tradesmen, artisans, and paupers in the several districts of the metropolis, supply analogous examples of erroneous selection and classification. In the great majority of the metropolitan parishes, for instance, there is no class of gentry properly so called; but this class consists, with the exception of a few professional men not improperly mixed up with it, of tradesmen who have retired from business long enough to be entered in the mortuary registers as gentlemen. On the other hand, the pauper class is very largely recruited from the ranks of the artisans and labourers, and contains a very considerable proportion of old persons who, being no longer able to earn their livelihood, have come upon the public for support.

The mean age of the living has been occasionally resorted to as a test or measure of salubrity. It has been assumed that a low average age of the living members of a class, when compared with the average age of another class, arises, *cæteris paribus*, from a high mortality leading to a quick addition of young members. This assumption is justified only in those cases in which the addition of young members can be shown not to arise from any other cause, such as an increased demand for members of the class in question. It is therefore a test to be employed with great caution; and it will also be necessary to show that the age of admission of the classes subject to comparison is the same, or open only to very slight variation.

2. *The rate of mortality.* — The mortality, or rate of mortality, is the number of deaths which takes place in a given population, in a given space of time. The calculation is generally made for a year, so that the ratio comes to express the number of the living out of which one will die annually. The ratio is sometimes stated as a fraction, and sometimes as a percentage proportion. If, for instance, out of a living population of 100,000, two thousand deaths take place every year, $\frac{2000}{100,000}$, or $\frac{1}{50}$, or 2 per cent. is the mortality, or rate of mortality, to which that population is exposed.

In estimating the value of this test, it is necessary to bear in mind that the rate of mortality varies for every year of life. It follows, therefore, as a natural consequence, that the rate of mortality, like the mean age at death, must be materially influenced by the ages of the living population. In a population containing a large proportion of young children, subject to a very high mortality, the aggregate rate of mortality for the entire population will be necessarily higher than in a population abounding in older persons and having a comparatively small number of children. But a very cursory examination of tables of mortality will convince us that the error attaching to the rate of mortality as a test or measure of the sanitary condition of a population is much less than that which is inherent in the mean age at death; for not only do the extremes of life approximate much more closely to each other in their respective rates of mortality than in the mean ages at death, but ages which, though less widely separated, are far enough apart to affect the mean age at death, are exhibited as subject to a mortality very nearly identical. From 5 to 10 years of age, for example, the rate of mortality, in the male population of England, is ·970 per cent., and from 20 to 30 years of age ·974 per cent.; so that, while out of 100,000 persons dying at the respective ages of 5—10 and 20—30, 970 and 974 persons would die in the year, their age at death would count in the one case as something between 5 and 10, and in the other at some age between 25 and 30. The difference in the rate of mortality would be almost nothing, while the difference in the age would amount to about 20 years. So also if we compare individual years instead of terms of years. The mortality at 10 years is ·791 per cent., at 20 years ·784 per cent.; at 11 years it is ·702 per cent., at 18 years .709 per cent. The rate of mortality differs very slightly in the ages brought under comparison, while the mean age at death differs by 10 and 7 years respectively.

These *à priori* reasonings are fully borne out by the results of actual comparison. In one of the reports of the Registrar General* the expectation of life (which will be presently shown to be the true test or measure of the sanitary state of a population), the mortality, and the mean age at death, for six different populations, are compared with each other, with what result the following table will show.

Expectation of life, in years: — Surrey, 45; England, 41; France, 40; Sweden, 39; Metropolis, 37; Liverpool, 26.

Rate of mortality, or one death in — Surrey, 52; England, 41; France, 42; Sweden, 41; Metropolis, 39; Liverpool, 30.

Mean age at death, in years: — Surrey, 34; France, 34; Sweden, 31; England, 29; Metropolis, 29; Liverpool, 21.

The rate of mortality, then, keeps pace with the expectation of life, to such an extent, at least, as to place the six communities in the same relative position; while, according to the mean age at death, the nations which stand third, fourth, and fifth on the list suffer transposition, France and Sweden taking rank before England in the scale of salubrity, and England, which holds, of right, the second place immediately after her own county of Surrey, is made to descend to the fourth rank. When compared, therefore, with an accurate measure of the duration of human life, the rate of mortality shows itself more worthy of confidence than the mean age at death. Nevertheless, for reasons already assigned, it must not be looked upon as altogether free from objection, and must, in every case, be regarded as of inferior value to the test next to be considered, namely,—

3. *The expectation of life.* — The expectation of life, or the mean future life-time, is the mean number of years which, at any given age, the members of a community, taken one with another, may expect to live. This expectation is embodied in those series of calculations which are technically known as life-tables, and which are so largely in use in the important operations of life-assurance. When correctly calculated, they are based on the two concurrent series of facts, the numbers and ages of the living and the numbers and ages of the dying, and they therefore comprise the two elements necessary to perfect accuracy. When based upon the ages of the dying alone, they are open to nearly the same objection as those which apply to the mean age at death.

The following is an abbreviation of the English life-table, which will be found given at length for any year of life from birth to 95 years of age in the fifth annual report of the Registrar General.*

Age.	Males.	Females.
0·	40·19	42·18
1·	46·71	47·55
2·	48·82	49·57
3·	49·52	50·29
4·	49·74	50·48
5·	49·64	50·38
10·	47·08	47·81
15·	43·35	44·13
20·	39·88	40·81
25·	36·47	37·52
30·	33·13	34·25
40·	26·56	27·72
50·	20·02	21·07
60·	13·59	14·40
70·	8·51	9·03
80·	4·92	5·20
90·	2·68	2·77
95·	2·22	2·06

The table is read thus: — At birth the expectation of a male child is 40·19 years, of a female child 42·18 years; at 5 years of age the expectation is 49·64 years for a boy and 50·38 years for a girl; at 20 years of age, males one with another may expect to live 39·88 years, and females 40·81 years; at 30 the expectation has fallen to 33·13 for men and 34·25 for women.

4. *The mean duration of life*, the mean life, the mean life-time, or *vie moyenne*, is found by adding the age to the expectation of life. Thus the mean duration of life at 5 years of age is 5+49·64 for boys, and 5+50·38 for girls, or 54·64 for boys and 55·38 for girls; at 10 years of age the mean duration of life is, for boys and girls respectively, 10+47·08 and 10+47·81, or 57·08 and 57·81; and at 30 years of age 30+33·13 or 63·13, and 30+34·25 or 64·25. The mean duration of life differs from the mean age at death, inasmuch as the one is a calculation based on all the deaths taking place, after a given age, in the members of a community traced through life, while the other is founded upon such deaths as happen to be noted in a community which has been undergoing continual disturbance by births, immigration, and emigration.

5. *The probable duration of life*, probable life-time, equation of life, or *vie probable*, is the age at which a number of children born into the world will be reduced one-half, so that the chance is equal of their dying before or after that age. Thus it has been ascertained that out of 51,274 males and 48,726 females (making up together the number of 100,000 infants) at birth, 25,637 males will die between the 45th and 46th year, or at about 45½ years of age, and 24,363 females between the 47th and 48th year, or at about 47½ years; so that the equation of life or probable life-time of males at birth is 45½ years, and of females

* Sixth Annual Report, p. 572.

* Report, p. xix.

47½ years. The same terms (probable life-time, equation of life, or *vie probable*) are also employed in speaking of persons who have attained more or less advanced ages. Thus the probable duration of life of a female at 25 years of age is about 41 years, being her actual age added to the number of years required to reduce the females living at that age to one half. In like manner the probable duration of life of a male aged 60 years is 73 years, being his age added to the 13 years required to reduce himself and his contemporaries to one half their number.

The term "specific intensity" has also been used as a measure of the value of life. It represents the number living at any given age, divided by the number dying at that age. For example, if, at the age of 44, 72,709 male survivors of the population of England and Wales, out of 100,000 born into the world, lose by death 990, the specific intensity is $\frac{72709}{990}$ or 73·475, while for the number of 72,190 female survivors losing 923 of their number, the specific intensity is $\frac{72190}{923}$, or 78·309. Females, therefore, have a higher intensity of life at 43 years of age than males; in other words, they suffer from a less mortality.*

Such are some of the principal methods which have been recommended or employed for ascertaining the true duration of human life,—a branch of statistical inquiry which has received large contributions of late years, many of which, however, are unfortunately rendered altogether valueless by the omission from the calculations of some elements necessary to precision, but not yet obtainable.

Bibliography. — 1. The fifth and sixth annual Reports of the Registrar General. — 2. Contributions to Vital Statistics. By *F. G. P. Neison, Esq.* — 3. Quarterly Journal of the Statistical Society, vol. vii. Essays by *Edwin Chadwick, Esq.* and *F. G. P. Neison, Esq.* at pp. 1. and 40. On the subject of the Construction, Properties, and Applications of Life Tables, which is intimately connected with Vital Statistics, many interesting details and full references to authorities will be found in *Mr. Farr's* letters to the Registrar General in the fifth and sixth Annual Reports.

(*W. A. Guy.*)

VOICE.†—(Syn. Gr. φωνη; Lat. *Vox;* Fr. *Voix;* Germ. *Stimme;* It. *Voce;* Span. *Voz.*) This term is usually applied to those sounds which animals produce by means of the air traversing their organs of voice, such as we observe in mammalia, birds, reptiles, and in some insects.

The human voice is susceptible of several modifications, such as *timbre* or quality, intensity, and pitch; including those successive transitions of tone from one pitch to another which constitute melody. The organs of voice comprise the thorax with the muscles of respiration, the lungs, trachea, larynx, pharynx, mouth, tongue, nasal cavities, nerves, and blood-vessels. Of these, the thorax and lungs may be considered an air-chest or bellows, the trachea a *porte-vent* or air-pipe, and the glottis a complex reed. The trachea varies in length and diameter with the age and sex of individuals, until they arrive at the adult period of life. By its structure the trachea is endowed with elasticity, together with the power of longitudinal extension and relaxation, and of increasing or diminishing in diameter: the acoustic effect of these properties will presently be investigated.

The sum of the areas of the two bronchi is greater than that of the trachea; by which adaptation the latter is more readily supplied with air during the vocalization of the breath. In all mammalia, birds, and reptiles, the axes of the bronchi are inclined to that of the trachea at a greater or less angle. With reference to the voice, the larynx is the most important organ in the whole apparatus. The mouth, fauces, tongue, and nasal organs are not necessary to the production of voice; nevertheless they exercise a considerable influence on its quality, and are indispensable for the production of articulate language. The thorax is sufficiently capacious to contain as much air after a full inspiration as will sustain the glottis in a state of vibration, when the tone is of moderate intensity, during the space of fifteen seconds, which will enable a person to pronounce in rapid succession from thirty to forty monosyllables at one expiration.*

The phenomena of the voice of animals must at a very early period have afforded to physiologists proof of the susceptibility of membranous structures to enter into a state of vibration; and it is now generally known that membranes, whether twisted into a cord like the string of a violin, or in the form of a parallelogram stretched in one direction as the vocal ligaments, or in that of discs stretched all round as the head of a drum, are all capable of producing musical sounds when properly excited.

The theory of the vibratory movements of stretched membranous surfaces has occupied the attention of many of the most celebrated mathematicians, such as Euler, Bernoulli, Riccati, Biot, Poisson, Sir John Herschel, and others. It is a subject requiring the most profound analysis, and the solution of problems of much greater complexity than those either of strings or bars; but in order to bring the theory of vibrating membranes within the reach of computation, the membranes are supposed to be homogeneous and of equal thickness and elasticity. Now this hypothesis will not satisfy the conditions of the vibratory movements of the vocal organs, such as the windpipe for example, which is composed of tissues of variable thickness, density, and elasticity; it would therefore be

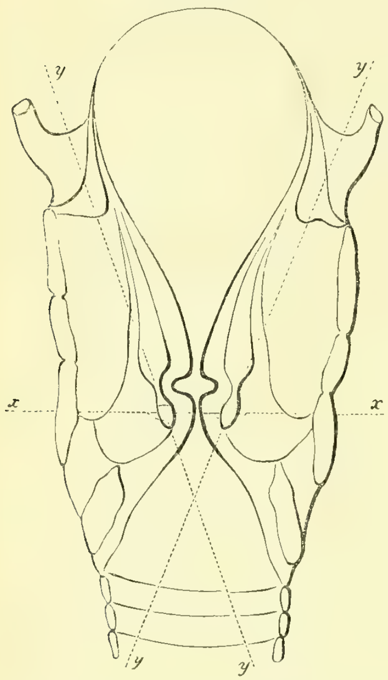
* See Contributions to Vital Statistics. By F. G. P. Neison, F. L. S. &c., p. 5.

† [It was intended that this article should have comprehended Voice and Speech. It is now found necessary to defer the latter subject to the Supplement. Ed.]

* For the anatomy of the human larynx, reference is made to the article Larynx.

futile in the present state of the science of acoustics to attempt any mathematical solution of the laws of the equilibrium and movements of the heterogeneous masses of the vocal tube. When, however, a membrane is stretched in one direction only, it obeys the same laws as a string.

Fig. 890.



An outline of the transverse section of the Human Larynx. (*Outline of fig.* 18, *Vol. III. p.* 100, *in which the different parts are indicated.*)

x, *x*, the plane of the vibrating position of the vocal cord; *y*, *y y*, *y*, the plane of the respiratory position.

Having adapted two laminæ of India rubber to a pipe connected with the bellows of an organ, M. Biot caused a current of air to pass over their free edges, by which means he obtained with facility sounds of different pitch. Professor Willis made similar experiments with leather and caoutchouc, but could not produce with these substances so great a range of tones as the glottis will yield, and therefore concluded that the vocal ligaments possess greater elasticity. Mr. Willis has also investigated the position in which it is necessary that membranous laminæ should be placed, in order that they may be excited and sustained in a state of vibration. He has likewise given a satisfactory explanation of the mode of action of the air on reeds, such as those of the organ pipe, which applies also to free reeds, and every other case where a vibratory motion is maintained by a current of air.

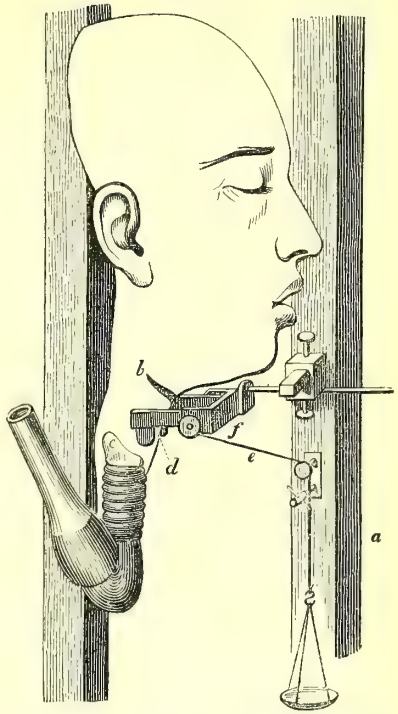
The experiments and theory of Mr. Willis are exceedingly important, for he has shown that in ordinary breathing the vocal cords remain inclined to each other, at an angle which prevents any vibratory motion; whereas when their surfaces lie in the same plane, the breath immediately excites them into a state of vibration; the natural position of the vocal cords in these two states is seen in (*fig.* 890). Müller also made some experiments on stretched membranous bands, both isolated, and in connection with a tube; from which he concludes that the force of the current of air influences the *pitch* of the note produced; so that a strong current will produce a more acute tone than a weak one, and *vice versa;* but the author has not found this to be the case in any of the experiments which he has made. To obtain a pure quality of tone when two membranous bands are stretched across a tube, it is necessary that they should be of equal weight and length, and subjected to equal tension, otherwise they cannot vibrate freely in equal periods of time. According to Cagniard De la Tour, if two membranous laminæ of equal length and weight be stretched by unequal forces, so that there is an interval of a fifth between the notes they yield separately, the note resulting from their combined action is the intervening third. Müller is disposed to doubt the accuracy of De La Tour, but his own views do not differ materially from those of the latter, as he says that when one tongue is most readily thrown into vibrations by the current of air, the sound is emitted by it alone, but if the blast is such that it throws them both into motion, they may both vibrate together, and by reciprocation produce a simple sound intermediate between the fundamental note of the two vibrating separately; they may also emit two distinct sounds, or the blast being modified, the two sounds may be produced in succession. From these researches it appears, that membranous laminæ, stretched in imitation of the thyro-arytenoid ligaments, will not only vibrate readily, but produce a range of musical tones. It has been remarked that sounds are most readily produced when the two laminæ are stretched in the same plane, and that a smaller volume of air is required the nearer the edges of the laminæ approach each other, and a still smaller one when their edges actually touch. De Kempelen states, that to produce sound, the edges of the glottis must be approximated to within $\frac{1}{10}$ or at least $\frac{1}{12}$, of an inch. These experiments upon artificial vibrating tongues perfectly agree with those the author has made on the larynxes of animals. Owing to the nature of the articulation of the thyroid with the cricoid cartilage, and the manner in which the crico-thyroid muscles act, an equal tension of both the thyro-arytenoid ligaments is simultaneously secured, supposing the arytenoid cartilages to be at the same time in corresponding positions, which is a necessary condition for the production of a synchronous vibratory motion in the two lips of the glottis.

If the larynx of an animal be dissected out, and the vocal cords be stretched, they will vibrate like a piece of caoutchouc or leather in a current of air. In conducting these experiments, it is necessary to secure the same conditions as those which are required in the laminæ above mentioned; for instance, the inner edges of the glottis must be turned towards each other till they are in the same plane and parallel to one another before they will produce any sound; hence we infer, that when the tension of the arytenoid ligaments takes place in the living animal, they turn upon their axes till their planes (which in the state of relaxation are inclined to the axis of the vocal tube) become perpendicular to it, and as the edges of the glottis approximate, and its chink is nearly or entirely closed up, they acquire the true vibrating position. The production of the most simple tones of voice requires the associated actions of a most extensive range of organs; and it is calculated that in the ordinary modulation of the voice, more than one hundred muscles are brought into action at the same time.

The lungs having been first supplied with air by the act of inspiration, and the air in the chest and trachea having subsequently been condensed by the muscles of expiration, a portion of the edges of the glottis yields to its pressure, and is curved upwards, so as to form an angle with the axis of the vocal tube, leaving between them a narrow aperture through which the air escapes. The tension and elasticity of the vocal ligaments tend to restore them to the plane of the vibrating position; the air having been rarefied below the glottis during their elevation, becomes condensed on their depression, and the necessary force is again accumulated to re-elevate the vocal ligaments, and thus an oscillating movement, consisting of a partial opening and closing of the glottis, takes place, which being communicated to the contiguous air, the sounds of the voice are produced.

The relative length of the vibrating edge of the glottis is regulated by the pressure of the column of air in the trachea, and the resistance of the vocal ligaments. The intensity of the voice in the same medium, and under similar collateral circumstances, depends on the pressure of the column of air in the trachea, and the range of motion performed by the vibrating edges of the glottis. The vocal ligaments do not vary the pitch of the voice by their tension alone, but by their variations in length and tension conjointly. The author has learnt this from his own experiments on the vocal functions of the larynx, which have been confirmed both by Majendie and Mayo; the former having observed in the larynx of a dog that a longer portion of the ligaments of the glottis vibrated during the utterance of grave tones, and that the length was diminished as the tones became acute. The latter had an opportunity of inspecting the movements of the glottis in a man who had made an attempt to destroy himself by cutting his

Fig. 891.

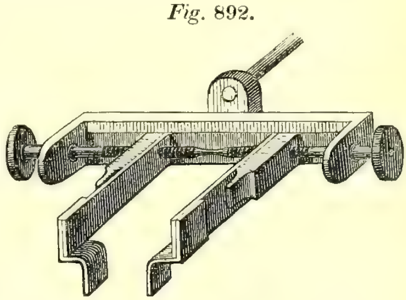


The Head and Vocal Organs prepared for experiments. (After Müller.)

The cervical vertebræ are removed, and the œsophagus opened behind the arytenoid cartilages, which are fixed together by a strong pin and ligature; the latter is brought through the opening, which is then firmly sewed together, and the lower opening of the œsophagus is also closed up. The larynx is laid bare, and the superior portion of the thyroid cartilage carefully removed so as not to injure the mucous membrane of the larynx. The parts thus prepared are firmly fixed against the column, to which the arytenoid cartilages are also attached by the cord which binds them together. The trachea is connected with a pipe and bellows for the supply of air.

a, the trachea; *b*, the os hyoides; *c*, the cricoid cartilage; *d*, portion of the thyroid cartilage remaining for the attachment of the cords *e*, by means of which the vocal cords may be extended; *f*, apparatus for compression.

Fig. 892.



The apparatus used for the lateral compression of the vocal cords, as seen in fig. 891 *f.*

throat. In this case the larynx was divided immediately above the vocal cords, and in consequence of the oblique direction of the wound, the arytenoid cartilage and the vocal cord on one side were injured. During respiration the glottis was observed to assume a triangular form, but when a sound was uttered, the chordæ vocales became nearly parallel, and the rima glottidis of a linear form. The posterior part of the aperture did not appear to be closed. In a second case of this kind, he observed that the arytenoid cartilages, as long as the vocalization of the breath continued, maintained the position which they had assumed when the glottis was closed entirely.* The vibrations of the thyro-arytenoid ligaments are considered by Ferrein † to be analogous to those of strings; hence he denominated these ligaments (though improperly) chordæ vocales. He imagined that the longitudinal tension of these cords alone governed the pitch of the voice. Mr. Willis ‡ has embraced the hypothesis of Ferrein; he observes, that to obtain the various notes of the glottis, it is only necessary to vary its longitudinal tension after the ligaments have been placed in the proper position; but M. Biot § remarks, "Qu'y a-t-il en effet dans la glotte qui ressemble à une corde vibrante? Comment pourroit-on en tirer jamais des sons d'un volume comparable à ceux que l'homme produit? Les plus simples notions d'acoustiques suffisent pour faire rejeter cette étrange opinion."

On inspecting the larynx from above, we see two very nearly rectangular-shaped laminæ, one on each side of the chink of the glottis, but nothing resembling an isolated cord. The mucous membrane which lines the thyro-arytenoid ligaments (to which it closely adheres), as well as the rest of the vocal tube, must be considered as forming a part of the weight of the vibrating surface upon which the air acts; the thyro-arytenoid ligaments confer on this membrane the requisite tension and resistance during vocalization, and it is this membrane which gives the sides of the glottis their laminated figure. The vocal ligaments, with their lining membrane, are stretched by the thyro-cricoid muscles, not all round like a drum, but in one direction only, namely, in that of their length, being attached on three sides, leaving one only free to vibrate. The vocal cords are, as has been seen, rectangular-shaped membranes, and from experiments made on the larynx after death by Ferrein, Müller, and others (which the author has repeatedly verified), are found to vibrate like cylindrical cords; we will therefore apply to the former the well-known formulæ which regulate the vibrations of the latter.

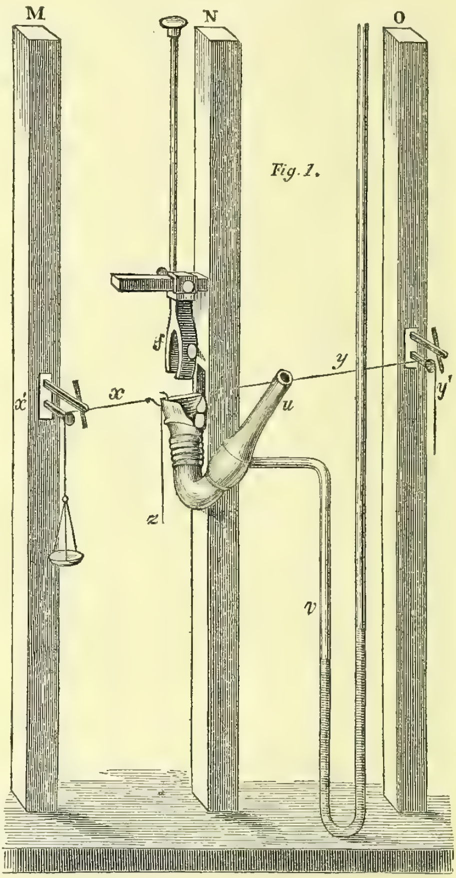
In cords composed of the same material, and of uniform thickness, the time of a complete musical vibration, or *double* oscillation, is

$$t=2\sqrt{\frac{lp}{2gP}} \quad - \ - \ - \ - \ (1.)$$

where l is the length of the cord, p its weight, P the force with which it is stretched, and $g=16\frac{1}{12}$ feet.

In order to apply this formula to the vocal ligaments, let a be their depth, b their breadth,

Fig. 893.



The apparatus employed for making experiments on the Human Larynx. (After Müller.)

N, shaft or column for the attachment of the larynx; f, the forceps for compressing the larynx laterally; u, the bellows pipe; v, the manometer connected with the tube u, for estimating the tension of the air used in the experiments. M, O, columns for the attachments of the pulleys x' and y'; x, a line by means of which the vocal cords are extended in the direction of their length; it passes over the pulley x'; y, a line passing over the pulley y', by means of which the vocal cords may be relaxed and reduced to their minimum length, thus performing the office of the crico-thyroid muscle; z, a line by means of which the vocal cords may be extended by drawing them downwards and forwards.

* Mayo, Outlines of Physiology, p. 991.
† Mémoires de l'Académie. 1741. p. 400.
‡ Cambridge Philosophical Transactions, vol. iv.
§ Précis Elem. de Phys. tom. i. p. 398.

and δ their specific gravity; then p will be equal to $abl\delta$, and equation (1.) becomes

$$t=2l\sqrt{\frac{ab\delta}{2gP}} \quad - \ - \ - \ - \ (2.)$$

and the number of such vibrations in 1″ will be

$$N=\frac{\sqrt{2gP}}{2l\sqrt{ab\delta}} \quad - \ - \ - \ (3)$$

We observe, in the first place, that if all other things remain the same, the number of vibrations varies inversely as the length of the cord; hence, if the vocal ligaments were divided by nodes into n ventral segments, each segment might be considered a separate vibrating ligament, whose length would be $\frac{1}{n}$th of the vocal cord, and consequently the number of its vibrations in a given time would be n times as many as that of the whole cord.

Owing to the elasticity of the thyro-arytenoid ligaments, their lengths, when in a state of repose, differ considerably from those which they present under the greatest tension. They differ also in the two sexes. In a series of experiments by Müller, the differences of length were observed to be as represented in the following table, the figures of which are in inches and decimals of an inch. From these experiments it appears that the lengths of the male and female vocal cords in repose are nearly as 7 to 5, and in tension as 3 to 2. In boys at the age of fourteen, the length is to that of females after puberty as 6·25 to 7, so that the pitch of the voice is nearly the same. These experiments afford an idea, although an imperfect one, of the elasticity of the vocal ligaments. It has always been a subject of surprise, if the thyro-arytenoid ligaments obey the laws of strings, how such short and narrow laminæ should produce such very grave tones as many bass singers are capable of uttering; and this struck M. Biot as one of the circumstances which in his opinion prove their mode of vibration to be unlike that of strings. He asks, "Où pourroit-on trouver la place nécessaire pour donner à cette corde la longueur qu'exigent les sons les plus graves?"

Subjects of Experiment.	Number of Experiments.					
	1.	2.	3.	4.	5.	6.
Male in a state of repose	0·7087	0·63	0·63	0·83	0·748	0·748
Male in the state of greatest tension	0·83	0·83	0·984	1·0236	0·9055	0·9055
Female in a state of repose	0·47244	0·47244	0·551	Boy of 14 in repose. 0·414		
Female in the state of greatest tension	0·63	0·59	0·63	Boy of 14 greatest tension. 0·571		
Mean length in male	In repose. 0·72834	Greatest tension. 0·912070				
Mean length in female	0·49868	0·61679				

The author is acquainted with some bass singers who can produce the note C which results from sixty-four musical vibrations. Let us now investigate this phenomenon more closely, and endeavour to explain how such grave tones are produced by such extremely short membranes. Müller has contrived several ingenious pieces of mechanism, seen in *figs.* 891, 892, and 893, by means of which he was enabled to estimate the amount of tension, lateral compression, and atmospheric pressure on the vocal cords, during the production of sound. In order to find the variations in the amount of condensation of air in the vocal organs in the production of sounds differing in pitch and intensity, the apparatus was furnished with a manometer (*fig.* 893, *v*). From that portion of the experiment which was confined to the investigation of the effects produced by tension of the vocal, compared with that of musical cords, he obtained results which are recorded in the following table.

Number of Experiments.	Weights employed.		
	4 loths.*	16 loths.	64 loths.
1	C	A^1	$G^2\sharp$
2	C ♯	B^1	$A^2\sharp$, A^2
3	$G^1\sharp$	$C^2\sharp$	C^3
4	A^1	D^2	C^3
5	A♯	$F^1\sharp$	G^2
6	A♯	$G^1\sharp$	G^3
7	D^1	C^2	A^2
8	$D^1\sharp$	B^1	A^2
9	G	G^1	G^2 both octaves imperfect.

* A loth = 225·5531 grs. English.

In the above table C^1 answers to 256 vibrations. Müller states that the numbers of vibrations in these experiments are not exactly in the direct ratio of the square roots of the stretching forces, and that the weights 4, 16, 64, did not produce the octaves, but generally from a semitone to two or three tones lower. Now this result should have been anticipated; but it does not seem to have occurred to him that whilst he increased the tension he at the same time increased the length, and we know (eq. 3.) that the number of vibrations in this case varies as $\frac{\sqrt{\text{tension}}}{\sqrt{\text{length of cord}}}$, and consequently the numbers actually produced by the weights above mentioned ought (agreeably to Müller's experiments) to be less than those which correspond with octaves. We see by the first experiment in the above table that the tension sufficient to produce 818 musical vibrations is 64 loths, or very nearly 33 ozs. If, therefore, we take the mean length of the vocal ligaments under the greatest tension at ·91 of an inch, and substitute in equation (3.) their values for all known quantities, remembering that P represents the tension of one vocal cord, we shall find the weight of each ligament, viz.

$$abl\delta = \frac{gP}{2lN^2} = 1{\cdot}144 \text{ grs.} \quad (4.)$$

In an adult male I found that the two vocal ligaments, when divested of mucous membrane, weigh one grain, which is scarcely one-half their weight by theory; hence it appears that a considerable portion of mucous membrane is connected with the vocal cord in the production of sound, which agrees with the anatomy of these parts.

It is now necessary to offer some explanation respecting the vital state of the vocal ligaments. The state of repose is the ordinary condition of the vocal ligament in the living subject, when the voice is not exercised; but we must not therefore conclude it to be incapable of further contraction. In fact, the state of repose during life is a state of tension, for the ligaments being connected with the thyro-arytenoid muscles, not in a few points, but continuously throughout their whole length, must obey the motion of these muscles, which, like all other muscles, are in a state of tension during repose. We also know by experience that when we produce a sound lower than the usual pitch of our voice, the crico-thyroid chink is opened principally by the contraction of the same muscles, and the ligaments must therefore at the same time be relaxed. It appears, then, both from the anatomy and physiology of the human larynx, that the ordinary state of the vocal cords is one of considerable tension, which admits of being lessened, and thereby produces the range of lower notes. If we suppose the glottis to be partially closed when we are talking, that is, at the ordinary pitch of our voice, and to be more opened as the tones become graver, this of course will co-operate with the relaxation of the vocal cords. In the production of the higher notes, the crico-thyroid chink closes, and the thyro-arytenoid muscles, and consequently the ligaments, are elongated. Since, therefore, the vocal ligaments have been proved to extend and contract for acute and grave tones respectively, and after death vibrate in a great measure like musical strings, we think it may be fairly inferred that they likewise obey, to a certain extent, during life, the laws of the vibrations of such strings, and that the conclusions which we have derived from the foregoing formulæ are not far removed from the truth. A further confirmation of these views may be derived from the following considerations. The length of a cord of invariable weight varies directly as the tension, and inversely as the square of the number of vibrations. Now, if we assume the length of the vocal cord, which gave $G^2\sharp$ under a tension of 32 loths to be ·91 inch, which is the mean length of the male vocal cord in its greatest tension, according to the first table, and which gave the notes A^1 C^1, under the tension 8 and 2 loths respectively, the corresponding lengths of that cord, according to the formula, will be ·83 inch and ·58 inch*; but ·58 inch is less than the least length in repose in the table. This result is, however, quite consistent with the theory here proposed; because after death the thyro-arytenoid muscle becomes of itself elongated, and consequently the vocal ligament attached to it, and therefore the length of the ligament must be greater in this state than when it is in that which we have defined to be the state of repose before it has lost its vitality.

In experiments made on the larynx by stretching the vocal ligaments with given weights, and by forcing a current of air through the glottis, care must be taken to keep the organs moist, and of the same temperature as they possess during life. The amount of condensation of the air in the vocal tube has been ascertained by Cagniard De la Tour, and Müller, the former in the living, and the latter in the dead subject. In a person who had an opening in the windpipe after the operation of tracheotomy, Cagniard De la Tour found that the tension of the air in the vocal tube, while blowing the clarionet, was equal to a column of water of thirty centimetres in height, and that to produce a simple vocal sound in the same person a tension of sixteen centimetres was necessary. Müller found that he could produce sound in a larynx artificially by a tension of 3·4 centimetres; but for very loud sounds an increased tension was requisite. The discrepancy between the experiments of Cagniard De la Tour and Müller may be ascribed to the circumstance that the one operated on

* N varies as $\frac{\sqrt{P}}{\sqrt{l}}$; $\therefore$ l varies as $\frac{P}{N^2}$, then ·91 inch : length of cord for A^1 :: $\frac{32}{(818)^2} : \frac{8}{(427)^2}$, the length of the cord for $A^1 =$ ·83 inch; and the length for $C^1 =$ ·58 inch.

the living vocal organs, but in a state of disease, the other on the organs after death.

Variations in the hygrometric and thermometric states of the air exert very powerful influence on the pitch of the voice; during the prevalence of a cold moist state of the atmosphere, especially in England, the voices of singers become lower by two or three notes, and regain their usual pitch when the air becomes dry.* In thus tracing out the analogy between the laws of stretched cords and those of the vocal ligaments, it is not intended that those ligaments should be considered as stringed instruments, but only that this analogy is accurate as far as relates to the velocity with which an impulse is propagated along them. Dodart † supposed the tension of the vocal cords to be merely subservient to an alteration in the size of the aperture of the glottis, and that the difference of $\frac{1}{54}$ of a fibre of silk, or $\frac{1}{384}$ of a hair in the dimensions of that aperture, was sufficient to alter the pitch of the voice; but this has been so completely refuted by more recent physiologists, and is so directly at variance with acoustic principles, that we need not give illustrations of its fallacy. M. Savart considered that the action of the air in its passage through the ventricles of the larynx, between the superior and inferior ligaments, is really the source of sound, and analogous to the mechanism of the bird-call or dog-whistle. ‡ There is certainly a great resemblance in the structure of that instrument to the space above mentioned in many of the higher animals, which might easily have led to this ingenious hypothesis; but, as we find neither superior ligaments nor ventricles of Morgagni in many of the order Ruminantia, in which the voice is very sonorous, this theory (as Müller remarks) is untenable.

We next come to the consideration of the alleged analogy between the action of the vocal ligaments and that of the reeds of musical instruments. This opinion is maintained by MM. Biot, Cagniard De la Tour, Majendie, Malgaigne, Müller, and several other distinguished scientific men. It is opposed principally by M. Savart, who observes that the *essential* principle of the action of reeds consists in the periodical opening and shutting of the orifice through which the stream of air passes, but that this is wanting in the glottis; and that were the latter a reed, the edges of the thyro-arytenoid ligaments which form the sides of the chink would be alternately forced asunder by the column of air in the larynx, and brought together by their tension; whereas he found by experiment that air blown through the glottis produced sound although its edges were from one-sixth to one-fourth of an inch asunder. M. Savart has however clearly mistaken the circumstance wherein the *essential* principle of reeds consists, since those of the clarionet, bassoon, hautboy, &c. do not entirely close the apertures through which the breath passes; and this is likewise the case with the natural reed formed by the lips of players on the flute and horn. There is in all probability a double action of the vocal cords in the production of sound; the one being a vibratory motion throughout their length similar to that of a musical string, and the other an oscillation like that of a reed, forming a partial opening and closing of the glottis. The author is led to adopt this view of the functions of the vocal organs from considering that every circumstance which he has established in his previous investigation of their action when treated as cords, is perfectly consistent with the hypothesis of their vibrating like the tongues of reeds; for let us now suppose them to be simply membranous tongues. In this case the axis of motion is the edge of the ligament attached to the thyro-arytenoid muscle; the vibrations take place in a plane perpendicular to the axis of that muscle, and the *length* of the tongue is the *breadth* of the ligament. The author has observed in repeated experiments on the larynx after death, that the chink of the glottis was partially opened and closed in the production of sound, and Müller found that by decreasing the breadth of the ligament he rendered the note more acute; but as this breadth is so small, being in its ordinary state in an adult generally less than one-tenth of an inch, it is extremely difficult to measure the variations corresponding with different notes; and the author cannot learn that any one has yet succeeded in determining these varying lengths with sufficient accuracy to form data for the application of the mathematical formulæ of elastic vibrating tongues.* We know that the number of vibrations made by the same tongue in a given time varies inversely as the square of its length. If, therefore, a tongue whose length is only ·1 inch give any note, the length necessary to produce the octave will be ·07 inch, that is, the variation will be only ·03 inch; we see then how minute must be the changes answering to the intermediate notes, and consequently how much more difficult it is to determine them in the vocal ligament when considered as a tongue than as a stretched membrane or cord. It is moreover observable that the extension and relaxation

* When Grassini came to this country, owing to the change from the air of Italy to that of England, her voice became one octave lower: after singing for two or three seasons, her natural voice returned, but it had lost its attractions with the low tones which had obtained her the greatest applause. Transactions London Medical Society, New Series, vol. i. 1846; art. Aphonia, p. 36.

† Mém. de l'Acad. des Sciences, 1700. 1701.

‡ See *fig.* 890.

* The formula of Giordano Riccati is

$$N = \frac{n^2 D}{L^2} \sqrt{\frac{2gR}{G}},$$

where N is the number of vibrations, D the thickness, and L the length of the tongue or rod, R its rigidity, G its specific gravity, g the space through which a body falls by gravity in 1″, and n a number constant for each mode of vibration, depending on the number of nodes.

of the vocal cord, which, as we have seen, are analogous to those of a musical string, produce a corresponding shortening and elongation of its axis, regarded as a tongue; and lastly, since one tone only is produced at a time, the vibrations resulting from the double action which appears to exist in the vocal apparatus must be synchronous.

We have seen how nearly, when we take into account the delicacy and difficulty of the experiments, their results agree with the theory that the vocal cords are subject to the same laws as other stretched laminæ, and it would be highly interesting to compare these results with the simultaneous variations which they undergo transversely, and thus discover how far the laws of vibrating elastic tongues may be applied to them. It might possibly be objected to the idea of this twofold action, that the production of sound by the vocal cords is sufficiently accounted for by supposing them to vibrate merely as elastic tongues; but then it is found by experiment, that by artificially dividing their length into two ventral segments, there results the octave of the fundamental note, which proves that at all events they vibrate as cords. In conclusion, we must ever bear in mind the vast difference between natural and artificial mechanism, and however complicated a problem it may be to determine that constitution of the vocal apparatus, by which the thyro-arytenoid ligaments may simultaneously obey the laws of cords and tongues, yet to a physiologist who is accustomed to meet with the most admirable contrivances and combinations in the animal frame, the difficulty of finding a strictly mathematical solution is, in such a case, no objection to its truth, when the facts, as far as they have been observed, are decidedly favourable to its reality. Were the movements of the glottis independent of any tube or column of air, the study of the functions of the vocal organs would be much more simple; but we find it situated nearly in the centre of the vocal tube of which the trachea and bronchi are the inferior, and the upper part of the larynx, pharynx, nose and mouth, the superior portion; we have therefore to consider the influence of this tube, and of its inclosed column of air in the production of voice.

In order to investigate the mutual relations between a reed and a pipe, two methods may be adopted: one of these is to vary the pitch of the reed while the length of the pipe remains constant, and the other to vary the length of the pipe with a reed sounding one tone only when detached from the tube. In the construction of reeded pipes for musical purposes, it is incumbent on the mechanician to adjust the length of the tube to the pitch of the reed. When a free reed is used on the principle of Kratzenstein or Grenié, it is found that, if the pipe be not in perfect unison with the reed, the purity of the tone decreases within certain limits, as the discordance between the reed and pipe increases. The researches of MM. Biot, Weber, Willis and Müller have greatly enlarged our knowledge on this subject. We learn from their experiments how great an influence is mutually exerted between a pipe and its reed, when the pitch of the one is made to vary while the other remains constant, and we may conclude that analogous effects are produced between the vocal tube and the glottis. The slightest knowledge of acoustics is sufficient to inform us that the pitch of any pipe, such as the organ, the flute, the trumpet, in short of all musical tubes vibrating in a similar manner, depends on the velocity of an impulse propagated in the air within, and is determined by the length of the pipe. As long as the tubes of musical instruments remain rigid, the nature of the materials which compose them does not affect the pitch of the sound, but merely influences the quality of the tone, and it is indifferent whether we employ metal, wood, or paper in their construction; each of these substances will yield a tone of a particular *timbre*, or quality, depending on the nature of the motions produced among its particles by the friction of the air on its surface; but the pitch will be the same in each, if the lengths of the pipes be equal, proving that the air itself is the source of sound. When, however, the sides of the tube are composed of flexible membranes, the inclosed air has a vibratory motion, conjointly with, and subordinate to, that of the parietes of the tube, whereby the pitch of the sound is affected, as well as its quality. M. Savart* found that by taking tubes composed of layers of paper of constant length, but varying in thickness, graver sounds were produced as the parietes became thinner, and that the gravity of the sound was increased by moistening and relaxing the sides of the tubes. We shall presently see the application of these facts to the vocal apparatus.

We find the flexibility of the trachea and bronchi capable of being varied by the operation of two forces, the one longitudinal or parallel to the axis of the tube, the other transverse. The first of these comprises the muscles which elevate and depress the larynx; the latter, the cartilaginous segments of rings perpendicular to the axis of the tube having muscular fibres attached to their posterior extremities, the contraction and elongation of which regulate the diameter of the trachea. The pharynx, mouth and nasal cavities, which form the superior extremity of the vocal tube, are also provided with muscles to modify the tension of that part of the tube so that it may vibrate synchronously with the rest. The necessity for this change in the dimensions of the tube, in order that it may vibrate in unison with the glottis, is in accordance, not only with the joint system of pipe and reed above described, but also with what actually takes place in the vocal organs of living animals. When the voice is raised in the scale from grave to acute, a corresponding elevation takes place in the larynx towards

* Annales de Chemie et de Physique, tom. xxxii.

the base of the cranium. By placing the finger on the pomum Adami this motion can be easily felt, and at the same time the thyroid cartilage is drawn up within the os-hyoides, and presses on the epiglottis; the small space between the thyroid and cricoid closes, the pharynx is contracted, the velum palati is depressed and curved forward, and the tonsils approach each other: the reverse of these phenomena takes place during the descent of the voice. These are the principal phenomena common to most mammalia which can be recognised by external observation; the other changes being, on account of their situation, invisible.

The effects of these variations on the tone of the voice have been hitherto little understood. It has always appeared incomprehensible why the vocal tube should apparently increase in length in the production of the acute tones, and shorten in the grave; a circumstance which theoretically presents an acoustic paradox. Dodart and many others have conceived the elevation of the larynx to be merely for the purpose of shortening the vocal tube in the supra-laryngeal cavity, and have considered the trachea as producing no effect on the pitch of the tone. Majendie has also pointed out the shortening of this part of the tube. In order to ascertain the effect of these changes, the following experiments were made on the dead body. Having laid bare the vocal organs of an adult male, I raised the larynx to the position it would occupy by the elevation of the voice to an octave, being about half an inch, and at the same time minutely observed the position of the lowest ring of the trachea with reference to the sternum. By this operation I found the trachea was raised out of the chest, nearly to the same extent as the larynx had been elevated towards the base of the skull. The next step was to examine whether any change had taken place in the diameter of the tube. For this purpose, having measured the diameter of the trachea in its natural position, the larynx was again elevated to the same extent as before, when the diameter was found diminished one-third. These experiments prove that, contrary to the general preconception, the elevation of the larynx *shortens* the tube independently of the contraction between the thyroid cartilage and os-hyoides, and at the same time lessens its diameter. The same effects may easily be detected during life by placing the finger on the trachea immediately above the sternum during the elevation of the larynx, when the trachea is found to ascend out of the chest, and afterwards to return to its former position; a movement in which the lungs and bronchi participate. The alteration of the tube in diameter may also be perceived by grasping the trachea with the finger and thumb during the elevation and depression of the larynx.* These movements are so striking as to lead irresistibly to the conclusion, that there exists a constant adaptation between the tension and the vibrating length of the thyro-arytenoid ligaments and the walls of the vocal tube, in the production of tones of the ordinary register; for we have seen that the variations of the vocal cords, at least as far as relates to the modulation of sound, are perfectly independent of the length of the vocal tube, and consequently the changes in its length which we have just described are not at all *necessary* for that purpose. Again, the vocal tube is so short, that, as has been ascertained by Weber and others, it could not, were it rigid, affect the pitch of the note produced by the glottis. As however this tube is composed of flexible materials, its effects are similar to those observed in M. Savart's experiments; that is, the relaxed state of the parietes compensates for its want of length, and enables it to vibrate synchronously, and therefore to give forth sounds equally grave with those of the glottis, thereby reinforcing the tone which would indeed be produced, though with much less intensity, without this aid.

The Falsetto, or *voce di testa*, has always been considered a most embarrassing subject of research, and its peculiar quality has excited the attention both of the physiologist and of the musician. Its most remarkable characteristic consists in its being less reedy in tone, and partaking nearly of the quality of the harmonic sounds of stringed and wind instruments. The change produced in the voice when passing from the falsetto into the common tone, or the reverse, is in some persons very sensible to the ear, whilst in others it is almost imperceptible. Some individuals, moreover, have the faculty of producing in the same pitch as many as eight or ten tones, possessing either the falsetto or the common character. The falsetto has been generally ascribed to some particular adaptation of the upper ligaments of the larynx. Dodart * has attempted to prove that it is a supra-laryngeal function, and that the nose becomes the principal tube of sound instead of the cavity of the mouth. Bennati † also considered these tones as being modulated by the supra-laryngeal cavity alone. This hypothesis, however, is untenable, since it supposes the column of air not to be influenced by the trachea, which is contrary to experience. In order to detect some of the movements of the larynx while the voice is passing from the first to the second, or falsetto register, it is only necessary to place the point of the finger in the crico-thyroid chink, when it is found that at the moment the transition from the primary to the secondary register takes place, this chink, which was closed during the production of the highest note of the ordinary register, suddenly opens on the production of the first note of the falsetto register, and consequently the thyro-arytenoid ligaments are relaxed at the same moment the

* Essays by the author, in the London and Edinburgh Philosophical Magazine, for September, October, and November, 1836.

* Mém. de l'Acad. 1707.

† Recherches sur le Méchanisme de la Voix humaine.

larynx falls, and the vocal tube is lengthened, although during these changes *the tones become more acute*. As soon as this has taken place, the larynx again rises as the voice becomes more acute. In a mezzo-soprano voice endowed with a double falsetto, or third register consisting of several tones of each register, with the power of producing tones of the same pitch either of the ordinary or the falsetto quality, we observed that the larynx fell at the commencement of each register, and that the thyro-arytenoid ligaments were twice relaxed, but in a much smaller degree. These observations have since been verified by many musical persons.

In order to explain the phenomena as connected with the production of falsetto tones, we must remember that at the highest note of the primary register the crico-thyroid muscles are contracted as much as possible in closing the crico-thyroid chink, and therefore that no further tension of the vocal cords can take place. In this state of things, the thyro-arytenoid muscles are at their maximum of elongation, and their transverse section is a minimum; consequently neither can a higher note be produced by an extension of the ligaments, nor are these muscles in a condition to affect the dimensions of the glottis; hence the necessity of some alteration in the state of the larynx in order to effect the scale of the falsetto, which is an octave above the ordinary register, and to prevent the mere repetition of the same series of sounds. This alteration might be produced in two ways; one of these is a partial closing of the aperture of the glottis caused by the action of the thyro-arytenoid muscles when they have returned to their ordinary condition, and are in a favourable state to produce that effect under the influence of the laryngeal nerves. For, let us suppose the larynx to be in the same state as at the commencement of the primary register, except that the chink of the glottis is half closed; the consequence will be that as only half the length of the ligaments can be made to vibrate, the *octave* of the lowest note in that register will result from the same tension which produced that note, and this will manifestly be repeated in consecutive notes of the range of the falsetto. This range is limited in general to a few notes, owing probably to the chink being soon completely closed by the stretching of the vocal cords. It is also owing to this partial closing of the glottis that a much less quantity of air is required for the falsetto than for the ordinary scale, which is proved by our being able to sustain a given note in the falsetto to a much longer time than we can sustain the corresponding note in the primary register. The partial closing of the glottis was observed by Majendie in his experiments on the dog, and by Mayo in the human subject. Another explanation was suggested by Gottfried Weber, namely, that the falsetto range is caused by a nodal division of the vocal cords producing harmonics of the fundamental notes, by which means the glottis acquires the same pitch as if it were half closed. If we consider the glottis as a reed, it is evident that since the number of vibrations must in this case be the same for the same note as when we suppose the ligaments to obey the laws of cords, the axis of vibration or the *breadth* of the ligament must be duly diminished, which may be brought about by the rotation of the thyro-arytenoid muscle on its axis.

Having thus considered how the glottis may act in the falsetto range, let us now examine in what way the vocal tube contributes to its formation. We have seen that this tube gradually shortens during the ascent of the primary register, suddenly falls to its original length when the falsetto commences, and again diminishes during the secondary register. Now it appears from Savart's experiments that, notwithstanding the shortness of this tube, the wave length of a column of air vibrating within it is the same as that of a rigid pipe of much greater length, and we have therefore strong grounds for believing that the notes of the primary register are reinforced in consequence of the vibrations of the glottis being always in unison with the fundamental pitch of the walls of the tube; hence in the falsetto, when the vocal apparatus has resumed its original condition, there will be less reinforcement of the sound, since the parietes of the vocal pipe are no longer in unison with the glottis, but give its grave octaves. We have found, by numerous experiments, that a flexible disc will vibrate to almost any pitch, but will reinforce the sound in a trifling degree only, unless the pitch be in unison with its fundamental note; and on the same principle we may suppose the intensity of the notes in the second register to be diminished, and their quality to be modified by the forced vibration of the walls of the tube, while in the primary all things concur in augmenting the effects produced by the glottis. Müller agrees with Lehfeldt in opinion, that the falsetto notes are produced by the vibrations of the inner portion of the borders of the vocal ligaments, and the variation of the pitch by their tension; and, although he does not mention by what mechanism this is effected, he seems to attribute it chiefly to the agency of the thyro-arytenoid muscles. The author's explanation is in many points coincident with that of Müller, but he has taken into account one or two circumstances which appear to have escaped Müller's attention. The natural key or pitch of the vocal organs may be found by sounding the voice, without either elevating or depressing the larynx. The grave octave of that note will be the fundamental sound of the vocal ligaments vibrating in their most relaxed state, with the glottis entirely open. Any tones of a graver pitch, produced by an unusually relaxed state of the vocal cords, lose both their quality and intensity, and cannot be included in the compass natural to the voice. According to the preceding principles, the pitch of the voice being usually an octave, or a fifth graver than the length of a column of air within the vocal pipe, we see the cause why a falsetto quality of sound cannot be obtained except during the production of acute tones. In many persons the speaking pitch is an entire octave graver than corresponds to the length of a tube, which would enable a column of air to produce the same sound; and in such persons the falsetto can seldom be effected. In consequence of the pitch of the vocal organs thus occupying a middle or central position between the acute and grave notes, a great facility is afforded to their action in modulating the voice. The vocal tube, like any other tube open at both ends, is said to be capable of producing the harmonics of its fundamental tone in the ratio of the series of natural numbers, 1, 2, 3, 4. These harmonic sounds have been described by Knecht of Leipsic, and by Dr. Young. I have occasionally thought that I have heard them during the forcible expiration which attends the boisterous laughter of children. The density of the air inspired is said to affect the pitch of the voice as in rigid tubes.

The influence of the epiglottis on the voice has been the subject of divers hypotheses. MM. Biot, Majendie, and Mayo have inferred, from the experiments of Grenié, that the epiglottis prevents the tones from becoming more acute when they increase in intensity. Liscovius, on the other hand, states that neither its depression, elevation, nor even its entire removal has any effect on the voice.* Haller appears to have deduced the same opinion from the circumstance of birds being destitute of this organ. "Epiglottis equidem nihil facit ad vocem, cum ea (vox) nata sit et perfecta quamprimum aer ex glottidis rima prodit, et absque epiglottide aves suavissime canant."† According to Müller, the influence of this organ on the pitch of the voice is exercised during its depression only, rendering the tones graver, and at the same time duller. He thinks we evidently employ it in this way during the production of very deep tones; and observes that, by introducing the finger at the side of the mouth, the epiglottis will be found to maintain the same position during the utterance of musical notes, whether they be of the falsetto character, or of the ordinary scale. I am disposed to ascribe to the functions of the epiglottis much the same value as Müller; since it is clear that its presence is not essential to the mere formation of voice, for it may be removed, together with the superior ligaments of the glottis, the ventricles of the larynx, and the capitula laryngis of Santorini, without impeding the vibratory movements of the glottis.

The art of singing consists in the application of the vocal organs to produce a certain succession of tones in some determinate order, which constitutes melody. This can be accomplished with precision by those only who can accurately discern with the ear, and imitate with the voice, the variations of the pitch of a musical instrument, or other sounding body. In many persons the perception of sound is defective; so that, whatever may be the purity and intensity of their notes as single unconnected musical sounds, they can never be used for musical purposes, that is, for sounds succeeding each other at regular intervals, governed by fixed rules. Many persons can imitate the voices of birds and beasts, and diversify the character of their tones to an indefinite extent. These performances illustrate the perfection of the human voice, but the artifices by which they are effected have no reference to the subject under investigation. The musical varieties of the human voice are classed according to their *pitch*, or the middle note of their primary register, which depends on the dimensions and physical constitution of the vocal ligaments. These varieties are, the *Bass*, the *Tenor*, the *Contralto*, and the *Soprano* *; the usual compass of each kind in the adult is represented in the annexed table.

Contralto. Soprano.

C D E F G A B C^1 D^1 E^1 F^1 G^1 A^1 B^1 C^2 D^2 E^2 F^2 G^2 A^2 B^2 C^3 D^3 E^3 F^3 G^3 A^3 B^3 C^3

Bass. Tenor.

In addition to these characteristic and principal divisions of the voice, there are certain others, called the *Baritone*, the *Mezzo-soprano*, and the *Soprano-sfogato*, which are subdivisions of the foregoing, and the place of either of which in the scale is indicated by its name. We see by this table what an extensive variety of harmonious sounds may be produced by the combinations of the different kinds of voice. In ordinary singers the range seldom exceeds two octaves, except in those endowed with a falsetto. There have been some celebrated singers, such as Catalani, Malibran, and others, whose compass has even exceeded three octaves, but such instances are rare. The voices in both male and female are nearly of the same pitch until the age of puberty, at which period the voice of males sinks an octave. This change of pitch is owing to a sudden enlargement of the larynx, the antero-posterior diameter of which is augmented by from one-fourth to one-third, with a simultaneous lengthening of the vocal ligaments. During this process the voice is hoarse, and there is a temporary inability to regulate it. Eunuchs do not undergo this change. Bennati is of opinion that the voice should not be

* Theorie der Stimme. Leips. 1814.

† Physiology, lib. ix. p. 372.

* The first two of these belong to the male sex, and the last two to the female. In this table C is the pitch of the 8-feet organ pipe, or the fundamental of the fourth string of the violoncello; the ciphers denote the octaves, that is, C^1, C^2, &c. are the first and second octave of C.

exercised at this time of life, and in support of his views he cited the cases of Donzelli and Donizetti, of whom the latter lost his voice by singing, whilst the former retained it by abstaining from singing at that period. There are, however, many examples of persons possessing fine voices, who never paid the least attention to this rule.

The oral, nasal, and pharyngeal cavities exercise an important influence on the quality of sounds after their production by the larynx. Further effects are ascribed by Bennati to the arches of the palate, the uvula, and velum, all of which appear to contract with the acute, and relax with the grave tones, and are in constant motion during the modulation of the voice. The contraction of these parts during the production of acute sounds has also been observed by Fabricius ab Aquapendente, Meyer, Gerdy, and Dzondi. Bennati conceived, as has been already mentioned, that the falsetto notes, which he calls notes "sur-laryngiennes," are produced exclusively in the superior part of the vocal tube; but it has been shown that this hypothesis is contrary to acoustic principles, and that the same motions of the palate are also equally observable during the production of acute tones of the ordinary register. Müller also states that the arches of the palate may be touched by the finger without altering the pitch, which could not be the case on the hypothesis of Bennati. It is to be remarked that neither Müller nor Bennati mentions the opening of the crico-thyroid chink on sounding the first note in the falsetto register; neither do they mention the simultaneous falling of the larynx, and they deny the existence of a third register. According to the hypothesis of Lehfeldt and Müller, any increased intensity of vocal sound ought to raise the pitch of the voice; but if this were the case, the performance of prolonged vocal sounds on the same note, but of variable intensity, would be rendered impossible without a simultaneous adjustment between the tension of the vocal ligaments and the current of air; whereas, by examining the state of the crico-thyroid chink during the utterance of these sounds, it is found that no such adjustment takes place. The exquisite quality of the sounds of the larynx, when modified by the oral and nasal cavities, renders the human voice far superior to any artificial musical instrument; since its tones glide through all the en-harmonic intervals between successive notes, an effect which no such instrument can perfectly imitate. Dodart estimates the number of tones which can be produced by the voice and appreciated by the ear in the compass of an octave, at three hundred: a striking proof of the complete control exercised by the laryngeal nerves over the vocal apparatus.

The action of the vocal organs in producing speech is a distinct branch of the physiology of voice, which the author has elsewhere investigated.* It is well known that the vowel sounds have been imitated by Kratzenstein, De Kempelen, and Willis, by means of mechanism, and that the principles on which they depend have been successfully analysed by the latter: but this is a subject which would require a very lengthened examination to render it the justice which its importance demands.

Having now completed the investigation of the physiological character of the human organs of voice, and having for the sake of simplicity considered them in three distinct lights, namely, as membranous ligaments obeying the laws of musical strings, as a reeded instrument, and as a membranous pipe with a column of air vibrating within it, the results of the various experiments which have been noticed would certainly seem to warrant the conclusion that each of these views is correct; for it cannot be denied that these experiments clearly show the vocal apparatus to be influenced by the air expelled from the chest in precisely the same way as if it were a stretched cord, a reed, or a vibrating tube. Why then should we hesitate to adopt the obvious conclusion that the vocal organs do in fact combine the properties of these various instruments, and are themselves the perfect types of which these instruments are only imperfect imitations? The error of those who have preceded the author in this inquiry seems to consist in viewing the organs of voice, not as a complex, but as a simple apparatus; with some the favourite hypothesis has accordingly been that of musical strings, with others that of a reed, while experiments are equally in favour of both.

It cannot be expected that in this brief treatise, a subject, wherein, notwithstanding the attention hitherto bestowed on it for many years by men of the highest philosophical talent, so little comparatively has been effected, should be at once exhausted, and all its difficulties removed; but the inductive method, the only satisfactory mode of reasoning on such subjects, has been most scrupulously pursued; and whatever explanations have been offered of the phenomena of the voice are at least founded on facts which are incontrovertibly established.

Comparative Anatomy and Physiology of the Organs of Voice. — Having given an outline of the structure and functions of the vocal organs in man, and stated our views of the principles on which the production of voice depends, we shall now proceed to the investigation of the physiology of voice in the lower animals.

Mammalia. — In the various orders of mammalia the organs of voice present different grades of development and complexity of structure, producing in each case some peculiarity of timbre, or quality of tone, by which we are enabled to distinguish them from one another. Some species are mute, such as the giraffe, armadillo, and others, whilst some possess voices of greater or less intensity.

The organs of voice in the lower mammalia, as well as in man, are composed of lungs, which, considered in an acoustic point of view, act

* Vide "On Articulate Sounds, and on the Causes and Cure of Impediments of Speech. London. 1851."

merely as bellows, the trachea or pipe, and the larynx* or reed. The nervous and muscular systems are similar to those of man, and do not require to be treated in detail. The acoustic principles of the first section will generally be applicable to the lower orders of Mammalia, so that when the structure is given the functions will be understood.

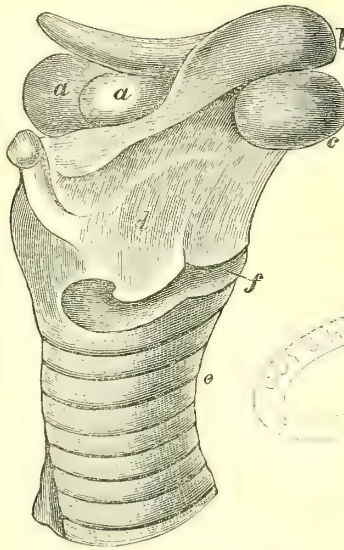
In the account of the anatomy of the vocal organs given by Cuvier, Vicq d'Azyr, Brandt, Wolff, Henlé, and others, no estimate is made of the relative dimensions of the larynx in the various classes of animals; therefore, in order that the reader may form an idea of their magnitude in Mammalia, compared with that of man,† it will only be necessary, in those which have a similarity of figure, to give the linear value of one of their dimensions, namely, that of the mean height of the superior margin of the thyroid, above the plane of the base of the cricoid, since their respective magnitudes will be as the cubes of those heights.‡ Also the lengths of the inferior thyro-arytenoid ligaments, when devoid of tension, are given. The letters H and L will be used to represent the heights and lengths respectively.

Quadrumana.—The vocal organs of the Quadrumana have already engaged the attention of several distinguished anatomists, such as Vicq d'Azyr, Camper, Hunter, Cuvier, Brandt, and others; and a condensed view of this part of the subject will be now given.

Chimpanzee. — Os hyoides: base concave, where a sac *b* (*fig.* 894) is lodged. Larynx, H. 0·8 in. Thyroid: margins, superior and inferior, nearly parallel. Cornua short; superior inclined upwards and backwards, inferior inclined downwards and forwards. Cricoid elliptical: margins, superior triangular, notch in front; inferior parallel to the first ring of the trachea, except in front, where it is depressed. Arytenoids small. Cuneiform curved, and in contact with the anterior margin of the arytenoids. Cart. Santorini — inferior thyro-arytenoid ligaments prominent. L. 0·5 in. to 0·6 in., superior thyro-arytenoid ligament not prominent. *Ventricles of Morgagni* oval, deep, leading to sac (*a*, *a*), lying between the epiglottis and arytenoid cartilage; right sac anterior to the left, convoluted, terminating in the concavity of os hyoides (*c*). Epiglottis: apex obtuse, trachea 16 rings. Voice more acute than in women; quality inferior: cause, sacculated larynx, &c.*

Orang-outang. — Larynx: volume equal to chimpanzee. Thyroid: wings united at an obtuse angle: margins, superior notched in mesial line. Cornua short. Cricoid elliptical: margins, superior and inferior, depressed in front; the latter connected with the first ring of the trachea. Crico-thyroid chink large. Arytenoids small. Cuneiform large and curved. Cart. Santorini: vocal ligaments,

Fig. 894.



Lateral view of the Larynx of the Chimpanzee.

a, *a*, sac connected with the lateral ventricles; *b*, os hyoides; *c*, sac protruding at the base of os hyoides; *d*, thyroid; *e*, trachea; *f*, cricoid.

inferior prominent; L. less than in woman. Ventricles oval, furnished with a canal penetrating the thyro-hyoid membrane. Sacs large, lie on each side the larynx. Ventricles valvular, rendering the inflation of the sacs under the control of the animal. Epiglottis broad, apex obtuse.*

Gibbons.—Os hyoides: base not excavated. Larynx, volume nearly equal that in orang; ventricles deep, communicating with a sac in Hylobates agilis, which lies in front on the thyro-hyoid membrane. Voice acute. Cry, bow wow.

Monkeys of the old continent.—Os hyoides: base excavated (*fig.* 895, B). Sim. Hamadryas, larynx destitute of sac.† Larynges perforated, sacs in the thyro-hyoid space. S. cynocephalus, S. mona, S. cercopithecus (*fig.*895, A), S. Malbrouch, S. Æthiops, S. rubra, S. Veter ‡,

* In the following description, the axis of the vocal tube is supposed to be perpendicular to the horizon, and not parallel or oblique, as is generally the case in the living animal.

† In man, we may assume the mean of H=1·5 in. and L=0·72834.

‡ In most Mammalia the figures of the larynges are similar; but in some orders they are dissimilar. For instance, in the *Cervus*, amongst the *Ruminantia*, the thyroid bulges out considerably in front, and in the *Sus scrofa*, amongst the *Pachydermata*, it is extremely narrow. In the *Cetacea* the whole larynx differs from those of all the other orders.

§ These measures relate to an animal not quite full grown, and are rather too small for an adult chimpanzee.

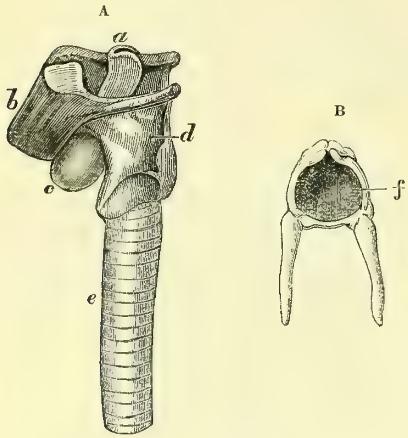
* According to Camper, the laryngeal sacs in the orangs disqualify them from applying the vocal organs to the use of articulate language; but this hypothesis is untenable, because language is independent of the quality, intensity, or pitch of the laryngeal sounds.

† Cuvier states that *S. Patras* has no sac or aperture in the larynx; this is, however, an error.

‡ Cuvier.

and S. Inuus *, two sacs. Laryngeal aperture situated at the base of the epiglottis, oval or circular. Voice acute ; quality hoarse : cause, laryngeal sacs.

Fig. 895.

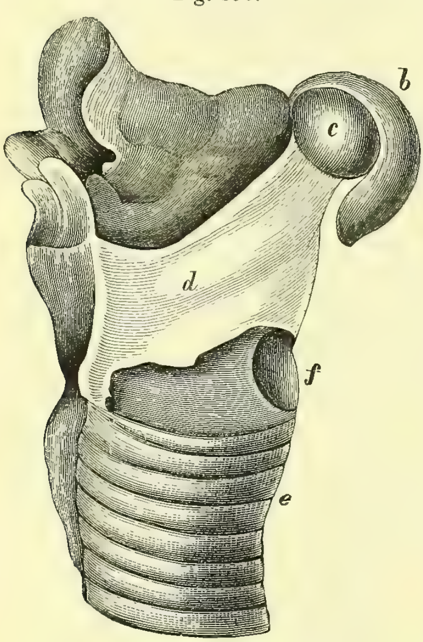


Larynx of S. Cercopithecus.

A. *a*, epiglottis; *b*, os hyoides; *c*, sac; *e*, trachea.
B. *f*, cavity of the os hyoides.

Albino Baboon. — Os hyoides: base, *b* (*fig.* 896.) excavated, inclosing a sac, *c*; Larynx: H. ·75 in.; Thyroid: upper margin concave, lower irregular; Cricoid: a vertical

Fig. 896.



Larynx of an Albino Baboon.

b, section of the os hyoides, showing the inclosed sac *c*; *d*, thyroid; *f*, crico-thyroid space; *e*, trachea.

ridge rising from the posterior surface, the cartilage tapering towards the anterior surface which is very narrow; Crico-thyroid space: large; Epiglottis: apex obtuse.

* Ludwig.

In the monkeys of America, some species have sacs appended to the larynx, the most complicated form of which is observed in

Simia Seniculus, or *Red Howling Monkey.*— Os hyoides, base excavated ; opening quadrangular. Thyroid, volume three times that of man.* Cricoid elliptical, nearly osseous. Pomum large and excavated, into which prismatico-oval sacs open ; sacs also communicating with the larynx by a semilunar opening at the base of the epiglottis. Arytenoids small. Cuneiform absent; instead of them, prominence.† Vocal ligaments: superior imbedded in tendino-cartilaginous masses ‡; inferior inserted at base of pomum. Ventricles passing on each side of epiglottis, which is connected with an infundibuliform sac, pomum, and oval pharyngo-laryngeal sacs. § Voice intense; howl discordant.

S. Appella and *S. Capucina.* — Os hyoides not excavated. Thyroid, cricoid, and arytenoid, like man. Cart. Santorini large, and curved backwards. Cuneiform absent; their place supplied by fatty tendino-cartilaginous masses meeting each other to form a channel for the passage of air: in shape like the letter S. ‖ Voice: quality like a flute, hence called Whistling Apes; expression, a plaintive melody, from which they are also called Weeping Apes.

S. Rosalia. Larynx perforated at the thyro-cricoid ligament, below the thyro-arytenoid ligament; aperture circular, sac small.

S. Coaita. Larynx like the Sapajous. Trachea dilated behind the cricoid cartilage.

S. Ateles arachnoides.—Os hyoides: base quadrangular, excavated. Larynx: cartilages of Santorini with masses substituted for cuneiform cartilage. Vocal ligaments: superior give rise to the cuneiform masses; inferior lie over the superior ¶ at their insertion.** Epiglottis: apex notched and connected with the cuneiform fibro-cartilaginous masses. Voice acute; quality hoarse; melody, a plaintive cry.

Lemur. L. gracilis. — Os hyoides: base not excavated. Larynx: no sac. H. 0·33 in. Thyroid: wings united at an obtuse angle; margins, superior oblique, inferior parallel to superior. Cricoid elliptical; margins, superior and inferior depressed. Crico-thyroid: chink large, rhomboidal. Epiglottis rounded; at its base a pit. L. 0·133 in.

L. tardigradus. Cornua elongated and united with first ring of trachea.†† In Lem. Mongoz and L. Catta are processes running from the epiglottis to os hyoides. Voice in Mongoz, a peevish kind of cry when irritated.

CHEIROPTERA. *Phyllostoma Spectrum.*—Os hyoides like that of Lemurs. Larynx: H. 0·5 in. Thyroid like the Lemurs; notch, superior absent; prominence small; margins,

* Brandt. † Ibid. ‡ Ibid.

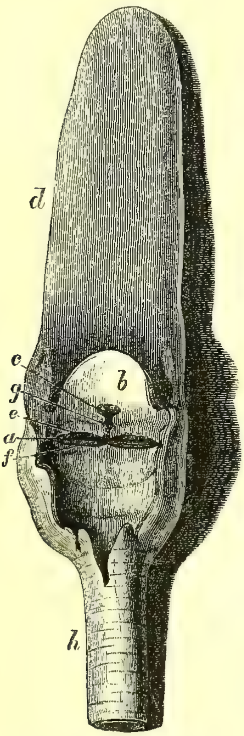
§ Humboldt describes six laryngeal sacs. Camper one. Vicq. d'Azyr, Cuvier, and Brandt more than one.

‖ Cuvier. Brandt. ¶ Cuvier.

** Brandt. †† Ibid.

inferior a notch ascending to middle of cartilage. Cricoid like that of Lemurs; margins, a notch in front, and a foramen on the right

Fig. 897.

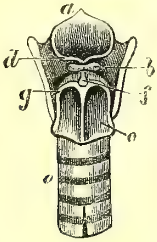


Larynx of S. Æthiops.

d, tongue; *b*, epiglottis; *c*, opening to sac; *e*, superior vocal cords; *f*, inferior vocal cords; *a*, ventricles of Morgagni; *g*, a vertical furrow; *h*, trachea.

side. Arytenoids as in L. Mongoz. Cuneiform cart. absent. Sesamoid oblong *b* (*fig.* 898). C. of Santorini triangular. Interarticular cart.

Fig. 898.



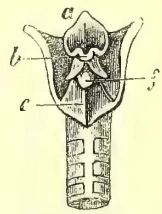
Posterior view of the Larynx of the Phyllostoma Spectrum.

a, epiglottis; *b*, sesamoid; *d*, junction of the cart. of Santorini; *f*, interarticular cart.; *g*, raised margins of cricoid cart.; *c*, surface of cricoid; *e*, trachea.

size of a millet seed, oblong (*f*). Vocal ligaments: superior not prominent; inferior narrow.* L. 0·2 in. Ventricles short. Epiglottis† rounded, with pointed projection on each side. Voice very acute, with a plaintive cry. Trachea 34 rings.

Insectivora. *Erinaceus Europæus.*—Larynx: H. 0·45 in. Thyroid: wings united in a short point. Cricoid a posterior vertical furrow *c* (*fig.* 899). Crico-thyroid: chink triangular. Epiglottis: apex acute; base divided by a fissure into two lobes, into which the vocal ligaments are inserted. Cart. of Santorini inclined forwards, having the interarticular cart.‡ between them *b*. Vocal ligaments: inferior strong. L. 0·176. Ventricles deep, leading to a sac§ situated between the epiglottis and os hyoides. Voice generally mute.

Fig. 899.



Larynx of Erinacea Europæa.

a, epiglottis; *b*, prominences of cartilages of Santorini; *f*, interarticular cartilage; *c*, furrow of cricoid cart.

Carnivora. *Ursus Malayanus.* Larynx: H. 1·55. Thyroid: wings unite at an obtuse angle; tubercle in mesial plane *a* (*fig.* 900), to which the epiglottis is attached; margins, superior ascending upwards, inferior excavated in front as far as the tubercles *b* (*fig.* 900). Cornua: superior short; inferior very long. Cricoid: superior margin inclined upwards, with a notch in front, by which the body is nearly cut through; inferior concave in front; lateral parietes held together by a transverse ligament. Arytenoids rhomboidal, between which are the sesamoids, *d d*, furnished with small muscles to approximate them. Cart. Cuneiform and C. Santorini present.‖ Epiglottis broad; apex obtuse. Vocal ligaments: inferior inclined upwards to the place of the superior, separated by a transverse groove. L. 0·833, or nearly equal those of man.

Ursus Arctos. See Wolff.

Syriac Bear. See Brandt.

Viverra Nasua. — Thyroid: wings united at an obtuse angle. Cricoid semitransparent.

* Vicq. d'Azyr states that the vocal ligaments are absent, but this is denied by Brandt.

† He is also in error in stating that the epiglottis is absent in the common bat.

‡ Brandt thinks that the interarticular cart. of Mammalia is represented by the Cricoid of Birds; but, as Henlé observes, there seems to be little foundation for this opinion.

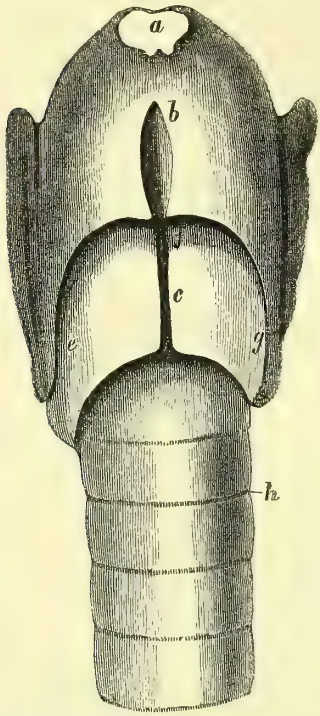
§ Wolff.

‖ These cartilages have been confounded with each other by Cuvier and Wolff.

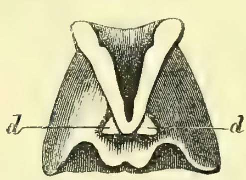
Epiglottis broad. L. 0·375 in. Voice more acute than in woman.

Meles Europæa.—Thyroid: margins notched in front. Crico-thyroid chink triangular. Ary-

Fig. 900.



Anterior view of the Larynx of Ursus Malayanus.
a, tubercle; *b*, notch of thyroid cart.; *c*, notch of cricoid cart.



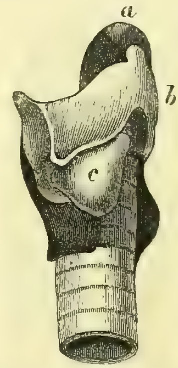
Showing the Sesamoid Cart. d d, of Ursus Malayanus.

tenoids small. Epiglottis triangular. Ventricles deep, leading to two sacs, one of which lies under the root of the tongue, the other between the thyroid and cricoid cartilages.*

Mustela Furo. See *Wolff.* Ventricles lead to sacs.

Lutra Vulgaris.— Thyroid : superior and inferior margins parallel and inclined upwards, superior terminating in a round apex, inferior hollowed out in front *b* (*fig.* 901.), and protuberant ; Cricoid, (*c*) inferior margin, so widely separated in front, as only to be slightly united at the inferior margin of the thyroïd. Epiglottis, oval but not large. Cart. of Santorini absent.

Fig 901.



Oblique view of the Larynx of Lutra Vulgaris.
a, epiglottis; *b*, thyroid; *c*, *c*, cricoid.

Canis familiaris. Thyroid : margins inclined upwards ; wings unite at an obtuse angle. Cornua : superior furnished with a transverse ligament running to the thyroid as in the hyæna. Cricoid : superior margin depressed in front. Arytenoids curved, and inclined from each other. Cart. Santorini and C. Cuneiform present. Ventricles deep. Epiglottis triangular, having a vertical furrow at its base. L. (and consequently the pitch of the voice) varies in almost every species; modulation expressive of emotion.

Felis Leo.—Larynx : H. 3·14 in. Thyroid : margins parallel, and inclined forwards and upwards; wings united at an obtuse angle; notch large below the pomum. Cricoid elliptical, ridge of Galen prominent. Cricothyroid : space large, rhomboidal, traversed in front by muscular fibres. Arytenoids rhomboidal. Cart. Santorini absent. Vocal ligaments : superior prominent. Ventricles deep, forming a sac between the vocal ligaments. Epiglottis : apex obtuse. Trachea 50 rings.* Voice grave, very intense ; roar terrific.

F. Tigris. — H. 1·8 in. L. 1 in. The superior ligament very prominent. In other respects the larynx resembles that of the lion. Voice more acute than the lion. Purrs like the cat.

F. Leopardus and *Catus.* — Larynges differ only in magnitude. The whole of the Feline order are remarkable for the prominence of the superior ligaments, by which the purring is most probably produced. *c* (*fig.* 902.)† Voice a mewing, which is well known ; also a melancholy cry by night.

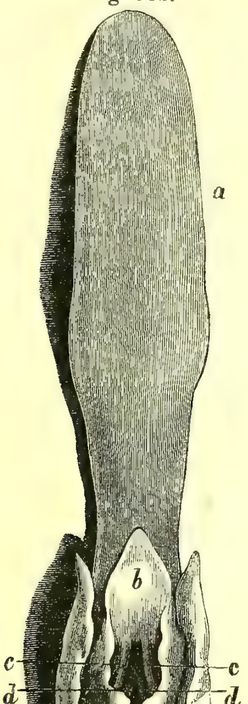
* Cuvier was of opinion that the posterior part of the vocal ligaments produced the vocal sounds.

* Vicq. D'Azyr and Cuvier state that the rings of the trachea are not entire. Perrault, on the contrary, describes them to be complete circles; but this is an error.

† Vicq. d'Azyr ascribed the purring of the cat to two thin membranes situated beneath the inferior ligaments; but we were unable to detect them : nor could Cuvier, Wolff, Casserius, and others, succeed in finding them.

Phoca vitulina, or *Common Seal*.—Larynx: H. 1·2 in. Thyroid: wings united by a small cartilaginous plate; cornua parallel to axis of

Fig. 902.



Larynx, Tongue, and Trachea of the Cat.

a, tongue; *b*, epiglottis; *c*, superior vocal cords; *d*, infinferior vocal cords.

vocal tube. Cricoid: depth of anterior to posterior surface as 2 to 5. Crico-thyroid chink rhomboidal. Epiglottis triangular, fixed to the thyroid by cartilage. L. 0·675 in. Trachea 78 rings.* Voice, nearly the pitch of a soprano; melody, a melancholy moaning.

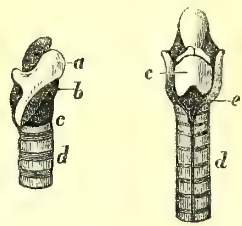
* According to Wolff, the first twelve rings are complete circles, the rest overlap each other.

MARSUPIALIA. *Kangaroo*.—Thyroid: margins, superior a notch in front. Arytenoids large. Cuneiform Cart., ventricles and superior ligament absent. Vocal cords membranous, fold upon themselves, so that they cannot be stretched* by the arytenoids. Voice, when in pain, moans piteously. †

Phalanger. ‡—Vocal cords: membranes substituted for vocal ligaments, but, as in the kangaroo, do not fold on themselves. *Common Phalanger:* vocal ligaments absent.

Didelphis Opossum.—(*Fig*. 903.) Larynx: H. 0·288 in. Superior ligament absent. Ventricles

Fig. 903.



1. *A lateral view of the Larynx of Didelphis Opossum.*

a, thyroid cart.; *b*, cricoid; *c*, crico-thyroid ligament; *d*, trachea.

2. *A posterior view of the same.*

c, cricoid cart.; *e*, laryngo-tracheal ligament; *d*, trachea.

very small. Inferior ligament: L. 0·176 in. Voice consequently acute; purrs like the cat. § Trachea 20 rings.

RODENTIA. *Paca*.—Epiglottis nearly semicircular; at its base a blind sac. Ventricles not deep. Vocal cords but little salient.

Cavia capybara. Larynx similar to that of the paca. Voice grunts like a pig.

Lepus cuniculus. *The Rabbit*. — (*Fig*. 904.) Larynx: H. 0·4 in. Thyroid: wings united at an obtuse angle; margins oblique and parallel. Crico-thyroid chink large. Arytenoids small, pyramidal. Cuneiform cart. curved. Vocal cords: superior thin and delicate; inferior prominent. L. 0·26 in. Epiglottis *a* obtuse; apex slightly notched, at the base of which are 4 conical cartilaginous bodies or tubercles inclined towards each other: between them, *b b*, is a triangular space; and a vertical groove passes between the insertion of the vocal ligaments from *b* to *c*. On each side a ligamentous filament descends, which acts on the tubercles above mentioned. The inferior tubercles give attachments to superior vocal ligaments and roof of the ventricles. Office of tubercles—to open the ventricles, stretch the superior ligaments, and give free-

* Cuvier.

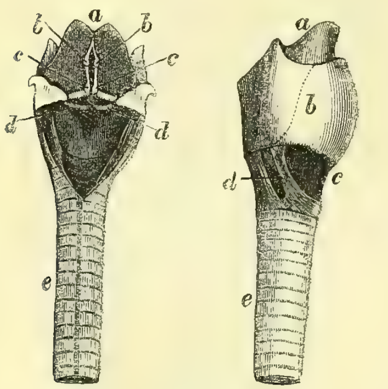
† Bennett's Wanderings in New South Wales.

‡ The Phalanger of Cook.

§ Cuvier describes two small vibrating membranes at the base of the epiglottis, which is denied by Wolff.

dom of motion to inferior ligaments. Voice acute.

Fig. 904.



1. *Larynx of the Rabbit laid open.*

2. *Side view of the same, externally.*

a, epiglottis; *b*, thyroid; *d*, cricoid; *c*, crico-thyroid ligament; *e*, trachea.

Hystrix cristata. Porcupine.—Vocal ligaments absent. Ventricles of Morgagni none. Voice mute.

Castor Fiber. The Beaver.—Larynx: H. 0·45 in. Epiglottis triangular, having a vertical raphe upon its posterior surface terminating in a sac bordered by the vocal ligaments. Arytenoids small and conical. Vocal cords: L. 0·25 in. Trachea 22 rings. Voice acute.

Mus Rattus. See details by Wolff.

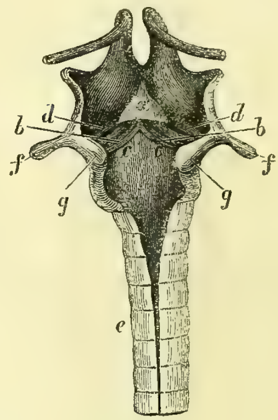
EDENTATA. *Ornithorynchus paradoxus.*—(*Fig.* 905.) Larynx: H. ·6 in. Thyroid: wings united at an obtuse angle; body partly cartilaginous, and partly osseous; supports laterally two transverse osseous processes *f f*, at the bases of which are two curved cartilaginous appendices. Cricoid elliptical. Arytenoid triangular. Ventricles not deep. A sulcus, *d d*, lies between superior ligament and cricoid cartilage.* Epiglottis: apex acute, *a*. Trachea 15 rings.

Armadillo.—Epiglottis bilobed. Voice mute.

Bradypus tridactylus or *Sloth.*—Larynx: Cart. of Santorini and superior vocal cords absent. Ventricles a mere impression. Inferior vocal ligaments free. Trachea convoluted. Voice a plaintive melody, consisting of an ascending and descending scale of the hexachord.†

PACHYDERMATA. *Equus.*—H. 1·85. Thyroid: wings united at an acute angle, and notched below to the pomum. Cricoid: margins, superior deflected inwards. Crico-thyroid chink inclined both vertically and horizontally. Arytenoids large; bases deflected from each other, by which the glottis is always kept open. Cart. of Santorini curved or hook-like bases fixed to the arytenoids. L. 2 in. Superior vocal ligaments not prominent. Ventricles of Morgagni oval, deep, *c c* (*fig.* 906) Epiglottis

Fig. 905.



A view of the internal mechanism of the Larynx of Ornithorynchus paradoxus.

a, epiglottis; *b*, superior vocal cords; *c*, inferior vocal cords; *d*, sulcus; *f*, transverse osseous processes; *g*, spines of transverse processes; *e*, trachea.

triangular, *a;* at the base two processes* connect it with the arytenoids. Between the commissure of vocal ligaments and epiglottis there is an oval cavity, *c;* and on the posterior surface of the epiglottis a groove, furnished at its base with a *semilunar membrane.*† Trachea 52 rings. Voice, the neigh, which is well known, but not easily described. Herrissant has exaggerated, as Cuvier states, the office of the semilunar membrane in the production of this singular sound.

Asinus vulgaris.—Larynx: H. 1·95 in. Thyroid: wings united at an obtuse angle. Cricoid elliptical. Crico-thyroid chink not large. Epiglottis: apex obtuse *a* (*fig.* 906.); at its base an arched cavity, *b*, in which the vocal ligaments are inserted. On each side of this cavity *c, c*, are two circular apertures, which lead to two large sacs situated behind the mucous membrane between the vocal ligaments and internal surface of the thyroid. L. 1·275 in. Trachea: rings spiral. Voice: quality discordant; range about 5 tones. The bray is well known.‡

Mule.—Laryngeal cavities similar to those in the ass. Voice, a species of bray resembling the voice of the ass, rather than that of the horse.

* This is described by Blainville, but Meckel seems not to have observed it.

† Bingley, An. Biog.

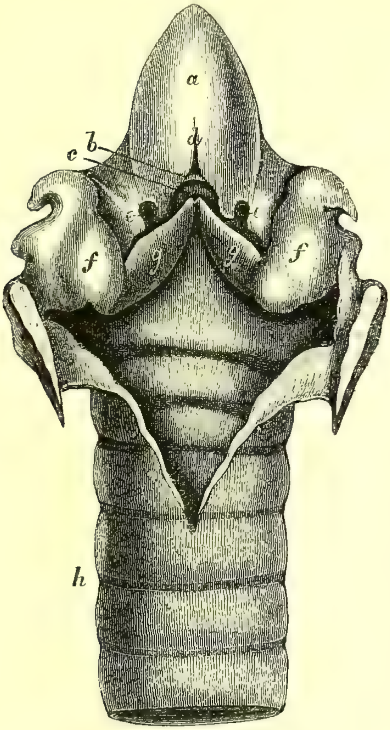
* These are the horns of the epiglottis of Casserius.

† The semilunar membrane of Herrissant.

‡ According to Herrissant, the edge of the arched cavity causes the peculiar timbre of the voice of the ass, and acts like the semilunar membrane in the neigh of the horse; both these hypotheses, however, are extremely doubtful; the sac mentioned in the text doubtless contributes largely to the production of the braying of the ass. During the bray an acute sound accompanies the inspiratory movement of the thorax.

Quagga.—Larynx somewhat like the horse, but destitute of semilunar membrane.* Voice resembling the bark of a dog; hence its name.

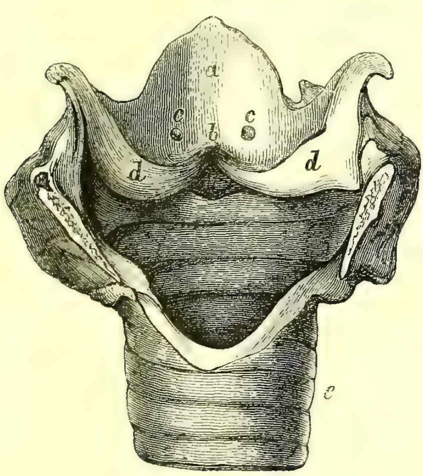
Fig. 906.



Larynx of the Horse laid open.

a, epiglottis; *b*, semilunar membrane; *c*, aperture at the base of the epiglottis; *d*, sulcus; *e*, ventricles; *f*, arytenoids; *g*, inferior vocal cords; *h*, trachea.

Fig. 907.



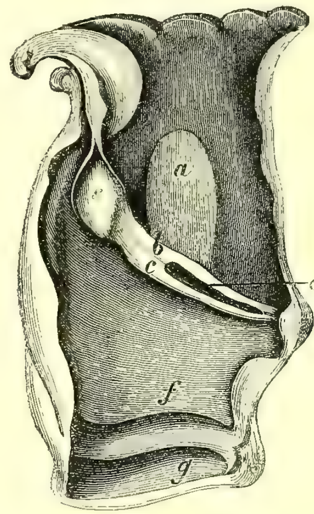
The Larynx of the Ass laid open.

a, epiglottis; *b*, arched cavity; *c*, apertures; *d*, arytenoids and vocal cords; *e*, trachea.

Tapir Americanus.—Larynx: H. & L. less than in the horse. Thyroid: pomum absent. For the Cart. of Santorini and Cart. Cuneiform, are substituted fibro-cartilaginous masses.† Vocal ligaments: superior short and indistinct; inferior strong. Ventricles elongated into an oval blind sac. A semilunar opening in the base of the epiglottis, leads to a curved cavity on each side of it.‡ Voice, a species of whistle.§

Sus scrofa.—Larynx: H. 1·55 in. Thyroid: wings united at an acute angle, become more acute below; superior cornua absent. Cricoid an eccentric ellipsoid. Arytenoids locked to each other at the apex of their superior prominence by a cartilage.‖ Vocal cords directed obliquely downwards to form, with the axis of the vocal tube, an angle of 30°, and are inserted at $\frac{1}{8}$ the height of the thyroid from its lower margin. L. 0·9 in. Ventricle *d* (*fig.* 908.) an oblong chink leading, by a groove inclined backwards, to a sac, *a*. Voice a grunting, discordant sound.¶

Fig. 908.



Mesial section of the Larynx of the Pig (Sus scrofa).

a, sac; *b*, superior ligament; *c*, inferior ligament; *d*, sacculus laryngis; *e*, left arytenoid c.; *f*, cricoid c.; *g*, trachea.

Rhinoceros.— Larynx: H. 5 in.; Thyroid: cornua none, figure rhomboidal. Cricoid:

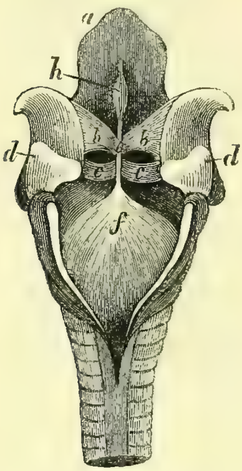
* Cuvier. † Brandt.
‡ Brandt. § Bingley, An. Biog.
‖ This cart. is peculiar to the pig.
¶ The larynx of this animal has been described by Casserius, Herrissant, Cuvier, Wolff, and Gurlt; the former first noticed the sacs in these words, 'Foramina duorum ventrium per quæ äer ingreditur, ad grunnitum in porcis efficiendum." Herrissant supposed the sacs to be the principal organs in the production of the voice of the pig, but we cannot concur in this opinion, they merely affect the quality of the sound.

nearly thrice as deep behind as in front; Crico-thyroid space very large; Ventricles of Morgagni large and deep; superior vocal cords prominent. L. 1·75 in.

Elephant.—Larynx: H. 4·83 in. Thyroid: wings united at an obtuse angle; surface externally convex; cornua, superior short; margins of inferior notched in front. Pomum a distinct cartilage. Cricoid elliptical; inferior margin concave; body deep, posteriorly passing over the first three rings of the trachea. Vocal ligaments: superior indistinct; inferior strong. L. 3·75. Trachea, 30 rings, which are often partially subdivided. Voice intense, of a grave pitch, aided by the proboscis.

Ruminantia. *Camelus Bactrianus.* — H. 3 in. Thyroid: wings united at an obtuse angle. Cricoid elliptical. Arytenoids triangular. Ventricles oval. Epiglottis: apex

Fig. 909



The Larynx of the Camel laid open.

a, epiglottis; *b*, superior vocal cords; *c*, inferior; *d*, arytenoid cartilages; *e*, vertical ridge; *h*, tubercle; *f*, trachea.

obtuse, posterior surface furnished with a tubercle. Vocal ligaments: superior rather broad *b b* (*fig.* 909); inferior strong *c c*. L. 1·5 in. Voice grave, but seldom exercised.

Llama.—Larynx similar to the camel. Vocal ligaments, superior and inferior, present.

Giraffe.—Vocal ligaments said to be absent.

Bos.—Larynx: wings of thyroid nearly equilateral, united at an obtuse angle. Cricoid massive, elliptical. Vocal cords: superior absent; inferior strong. L. 0·85 in. Trachea 52 rings. Voice sonorous, intense, pitched in C = 256 vib. in 1″.

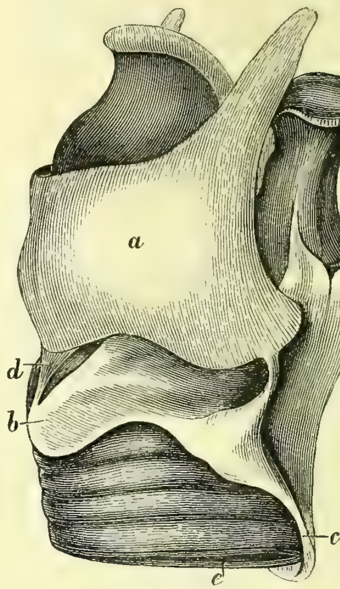
Ovis Ammon.—Larynx differs from *Bos* only in dimensions. Voice guttural, pitched in F = 341 vib. in 1″.

Antelope. A. Dorcas, and *A. Corinna.*—Larynx perforated by an aperture at the base of the epiglottis leading to a sac. A. gutturosa, pomum very large.*

Cervus. C. Farandus or *Rein Deer.* — Larynx has a laryngeal opening at the base of the epiglottis †, leading to a large sac.

C. Alcas. H. 2·5 in. Thyroid: wings united at an obtuse angle; cornua long; pomum large, and concave within. Cricoid: posterior deep, shielding the five first rings of the trachea; anterior narrow. Crico-thyroid chink *c* (*fig.* 910) broad; crico-thyroid ligament strengthened by additional perpendicular fibres *d*; its superior ligament absent, inferior inserted into the concavity of the pomum. L. 1·8 in. Voice grave.

Fig. 910



Larynx of Cervus Alcas.

a, thyroid c.; *b*, cricoid; *d*, crico-thyroid ligament.

C. Capreolus.—Larynx: H. 1·85 in.—Thyroid: wings united at an obtuse angle. Cornua: superior long, inferior shorter, curved; pomum large, concave within. Cricoid, eccentric ellipse. Body: posterior deep, anterior narrow. Crico-thyroid chink large. L. 1·26 in. Voice grave.

Cetacea. *Balænoptera rostrata.*—H. 10 in. Thyroid: wings united at a very obtuse angle ‡, the superior margins being nearly straight; inferior excavated by a triangular notch near the centre. Cornua: superior absent; inferior very large, straight, but curved in the dolphin. Cricoid: deep behind, absent in front, where it opens into a large sac §

* See Pallas, Spicil. Zoolog. fasc. xii. fig. 16.

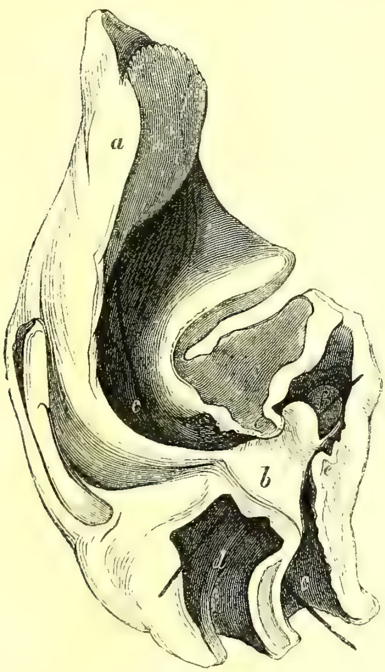
† See Camper, Naturges. des Orang-outang, &c.

‡ Indeed the wings spread open almost into a straight line.

§ This sac has been described by Hunter and Sandifoot. In the dolphin and porpoise the cricoid is imperfect in front.

lying in front of the larynx. Tracheal length 4 in.; posterior cartilaginous, anterior membranous at its laryngeal extremity. Arytenoids: superior prominences elongated, flattened, and inclined forwards — their inner margins lie in contact; the inferior

Fig. 911.



Section of the Tongue, Pharynx and Larynx of the Porpoise.

a, pyramidal position of larynx; *c*, pharynx; *d*, laryngeal cavities laid open, and a bristle is passed though the glottis, *f*.

prominences short, but strong. Epiglottis: base springs from the superior margin of the thyroid, to which it is fixed by a cartilaginous union. It is flattened and directed backwards to unite with the superior prominence of the arytenoids, with which it completes the aryteno-epiglottic portion of the vocal tube. The diameter of this portion is narrower than the rest of the tube, which crosses the fauces, enters the posterior nares, and terminates in the olfactory organs. In its passage it is grasped by a strong sphincter muscle of the fauces, as in the porpoise, *e e* (*fig.* 911). Vocal ligaments absent. Aperture of the vocal tube, in those which have but one opening, as the spermaceti and bottle-nose whales, grampus, dolphin, and porpoise, transverse; but in those which have two apertures*, as in the great whale-bone whale, it is longitudinal. Thyroid gland absent. Voice absent, or reduced to a single lowing. Trachea, in *Balænoptera rostrata*, length 4 in.; posterior cartilaginous, anterior membranous at its laryngeal extremity.

Birds.— The vocal organs of birds differ from every other class of animals by the constitution of the superior, and by the addition of an inferior larynx. The same acoustics apply, with few exceptions, to all Mammalia, but in birds is required an additional investigation.

The superior larynx of birds is situated immediately below the os-hyoides, to which it is connected by the thyroid membrane, and hyo-aryngeal muscles. Its figure and structure are more uniform than those of the inferior larynx. It is partly cartilaginous, and partly osseous.

The thyroid cartilage forms the anterior, and part of the lateral boundary of the larynx, and rests upon the first ring of the trachea. Wings, superior margin ascending forwards and upwards, meet each other in the mesial line, where the cartilage terminates in either a pointed, rounded, or flattened projection; inferior margin usually horizontal, corresponding to the first ring of the trachea, as in Palmipedes, but are excavated in Scansores. The posterior margins terminate in two quadrangular bones, with which the thyroid cartilage is frequently ossified (and these then become portions of the wings of the thyroid ; the quadrilateral bones, being also oblique angled, are shaped to form a union with the posterior margin of the thyroid, and present horizontal edges above and below, leaving a small triangular space for the cricoid cartilage posteriorly. The cricoid is a small triangular bone, lying on the inside of the posterior edges of the two quadrangular bones; it supports the two arytenoid cartilages, as in Mammalia; and although it forms a very small portion of a ring, it is yet necessary for the completion of it. These four bony or cartilaginous pieces are most distinct in young birds, and amongst old ones are quite distinct in the *Anas domesticus* and *Anas mollissimus*, but are consolidated into one in the Scansores, ostrich, and many others. The arytenoid cartilages are long and tapering upwards and forwards, and form by their inner margins laterally the rima glottidis: they are generally ossified. Their external margins are bounded by the thyroid cartilage, and their inner margins form the rima glottidis.

Epiglottis.— In most birds the epiglottis is situated on the internal surface of the thyroid; it is rudimentary, and is termed the processus epiglotticus: it is generally osseous, but according to Henlé it is leaf-like in the stork and heron; and in some of the Gallinaceæ, as in *Sterna*, *Rallus*, and *Larus*, it is thin, flat, and flexible, as in Mammalia.

Rima glottidis.— The form of this chink in a state of repose is triangular, the apex being directed backwards: it is bounded an-

* Hunter remarks that the cartilages of the larynx are much smaller in the bottle-nosed whale of twenty-four feet, than in the piked whale of fifteen feet. He is also of opinion that the absence of the vocal cord, co-existing with that of the thyroid gland, tends to show that the functions of the latter are in some manner associated with those of the former.

teriorly by the thyroid, laterally by the arytenoids, and posteriorly by the cricoid cartilage, but is destitute of salient membranous laminæ.*

Muscles. — The superior larynx is raised by the hyo-thyroideus and the thyro-trachealis muscles, and depressed by the hypsilo and sterno-trachealis. The glottis is opened by the thyro-arytenoideus posticus, and closed by the thyro-arytenoideus lateralis, as in the higher order of reptiles.

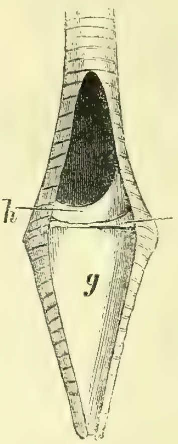
The superior larynx is supplied by the superior laryngeal nerve alone, the inferior laryngeal terminating in the inferior larynx and trachea.

The inferior larynx. — This organ is peculiar to birds. It is exceedingly diversified in form and structure. It is always found except in the condor, and other vultures. If we make a section of the lower larynx of birds in the mesial plane, its lateral segments, if viewed separately, present a double organ of sound; the exceptions to this rule are, the parrot, perroquet, and cockatoo. The inferior larynx of birds is often a very complex structure, and may be considered a double reed furnished with a pipe. It is symmetrical in most orders of birds except the Palmipedes, and is situated between the last ring of the trachea and first of the bronchi; it lies upon the œsophagus posteriorly, where there is generally a triangular space for the passage of that tube.

The frame-work of the inferior larynx is formed by the developement of several lower rings of the trachea, which take diversified forms in different orders of birds, and sometimes in the sub-genera of the same order, as in *Mergus* and *Anas* among the Palmipedes. In those birds which have a pure quality of voice, and whose instinct excites them to produce a continuous succession of tones, constituting some defined melody, we find the inferior larynx not only better adapted to produce a purer quality of tone, but it is provided with a greater number of muscles for modulating the voice.

Among the Insessores, the Corvidæ and Sylviadæ have the external walls of the inferior larynx composed on each side of three semilunar bones which are developed from the inferior portion of the trachea. The larynx is bounded internally by a bone, which traverses the lower end of the trachea, the vertical longitudinal section of which coincides with the plane of the mesial section *i* (*fig.* 912): this os transversale, after stretching across the tube, divides at each end into two laminæ, which diverge laterally from the axis of the bone to meet the two first external bones of the larynx, thus strengthening and completing its solid framework. The superior part of the os transversale is concave, and furnished with a very thin delicate membrane, rising vertically from the bone *h* (*fig.* 912): this is called by Savart the *membrana semilunaris.*

Fig. 912.



Section of the lower Larynx.

h, membrana semilunaris; *i*, os transversale; *g*, membrana tympaniformis.

This membrane is most developed in singing birds, and is considered by Savart to be one of the most essential organs of voice in the inferior larynges of the nightingales, thrushes, linnets, finches, and other singing birds, as well as in speaking birds, such as the pies, jays, &c. The inferior edge of the *os transversale* gives attachment to *the membrana tympaniformis.*

Bones of the inferior larynx. — The first bone *a* (*fig.* 913) is flattened and curved, being convex externally, and concave internally: it forms the boundary of the internal lateral face of the larynx.

The second bone *b* (*fig.* 913) presents nearly the same form as the first, but it possesses greater mobility, the muscles which are inserted into it drawing it upwards and out-

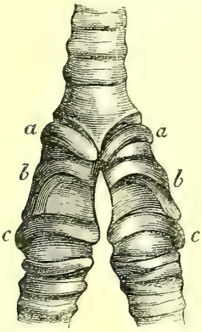
* Although anatomists are generally agreed respecting the position and figure of the several pieces which enter into the formation of the superior larynx of birds, they differ widely in reference to the parts which they represent when compared with man. Cuvier conceives that the posterior cartilage, which Humboldt [1] calls sockel, represents the cricoid of Mammalia, and that birds are destitute of epiglottis, thyroid, and arytenoid cartilages. Fabricius [2] considers it best to divide the pieces into three parts, viz. two arytenoids and an os-innominatum. Tiedemann [3] thinks the anterior piece represents the thyroid, the quadrangular pieces the cricoid, and the triangular the arytenoid cartilages of Mammalia. Meckel [4], on the contrary, considers the triangular pieces to be the cricoid divided. Carus [5] supposes the quadrangular pieces to be arytenoids, and the triangular the cartilages of Santorini. Wagner [6] unites the single with the quadrilateral pieces for a cricoid, and the triangular for the arytenoids.

[1] Observations de Zoologie.
[2] De Larynge. P. i. cap. vii. In op. omnia. Lips. 1687, p. 273.
[3] Zoologie, b. ii. p. 644.
[4] Archiv. für Anat. und Physiol. 1832, p. 324.
[5] Lehrbuch der Vergleichenden Zootomie, b. i. p. 195.
[6] Lehrbuch der Vergleichenden Anatomie, p. 242.

wards perpendicularly to the axis of the bonchus of the same side, by which means the area of the latter is varied.

The third bone is but very slightly curved (*c*). It is separated from the second bone by a triangular membrane; having its extremities articulated to the second bone by ligaments which permit of an extensive freedom of motion, particularly of a rotatory movement on its axis, and it is an important agent, according to Savart, in modulating the voice. The internal surface of this bone is lined with a fibrous cord which forms the external lip of the glottis. The posterior extremities of these three bones are not united, but have a triangular space between them for the passage of the œsophagus.

Fig. 913.



Inferior Larynx of the Raven,

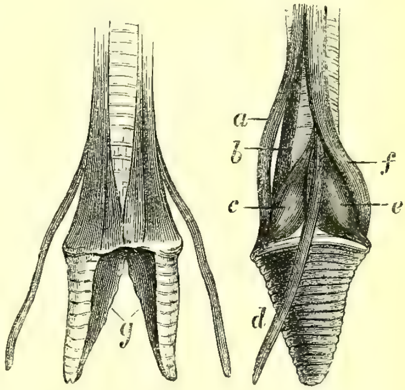
Shewing the three bones, *a*, *b*, *c*.

The Membrana tympaniformis.— This is a thin transparent membrane, extending from the os transversale to the extremities of the bronchial half-rings *g* (*figs.* 912 and 914): it forms the internal surface of the larynx and bronchi, and is a continuation of the semilunar membrane; so that the tympaniform and semilunar membranes are stretched simultaneously, and the latter is acted upon through the instrumentality of the former.

The Arytenoid Cartilage. — This is a small body situated at the head of the second bone: it is described by Savart as being of a lozenge shape in the starling, but very short in the nightingale. This form of larynx in the Corvidæ and Sylviadæ is provided with *six* pairs of muscles.* (See *fig.* 914.)

Palmipedes. — In the genera *Anas* and *Mergus* the inferior larynges of the males only are unsymmetrical, and composed of bony cavities. In the *Anas domesticus*, the inferior larynx presents osseous cavities formed by the developement and union of the last six or seven rings of the trachea. It is divided within into two unequal cavities by the *os*

Fig. 914.



1. *The inferior Larynx of the Raven,*

Shewing the six muscles, *a*, *b*, *c*, *d*, *e*. *f*, which modulate the voice on one side.

2. *Anterior view of the same,*

Shewing the membrana tympaniformis, *g*.

transversale, of which the left is always the largest. The figure of the os transversale is very similar to that of the arytenoid cartilage in the human larynx, consisting of prominences, ridges, and base: the superior prominence of this bone projects high into the tube of the trachea, and completely divides the larynx at its base. The ridge on its left side is furnished with a salient lamina, corresponding to a thin transparent semilunar lamina, situated opposite to it: the latter is placed at the entrance of a small osseous cavity at the inferior boundary of the left larynx; a still larger osseous cavity lies obliquely above the semilunar membrane. The air sets this membrane in motion as it circulates in the left chambers of the larynx, and contributes to the production of the well-known peculiar character of voice in this bird. On the right side the cavity of the larynx is of smaller dimensions, of less irregular form, and destitute of those prominent ridges and salient laminæ within. There appears to be a small tympanic membrane attached to the first few rings of the bronchus on the right side.

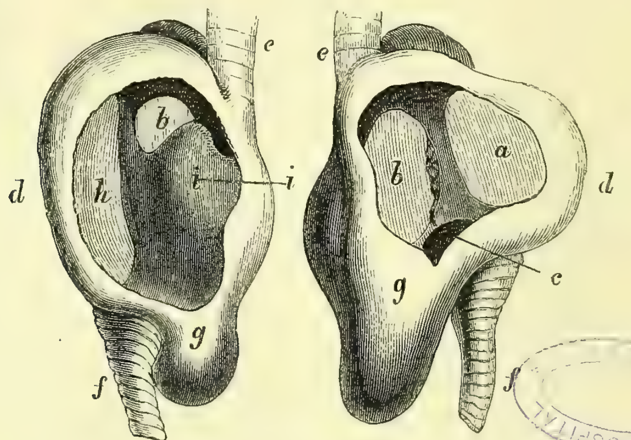
In the *Mergus serrator* the inferior larynx is partly osseous, and partly membranous: it consists of two irregular cavities. The os transversale, *i* (*fig.* 915), which has an extensive union along its posterior edge and base with the bony boundaries of the larynx, divides this tube into two parts, except at its superior prominence, where it leaves a channel *b* for the air from the right bronchus *f*, to penetrate the trachea. On the right lateral surface of the larynx, a large oval membrane

* These muscles are given in detail by Savart, *Mémoire sur la Voix des Oiseaux*, in the *Ann. de Chem. et de Physique*, vol. xxxii., also Cuvier, in the *Règne Animal*, vol. iv. There are five pairs of muscles assigned to the inferior larynx of the singing birds by Cuvier, Mr. Yarrell, Professors Grant and Owen, but six can be made out in the Corvidæ, as stated by Savart, and seen in the figure of the Raven.

forms the boundary : the rest of this cavity is composed of bone. On the left side the larynx is furnished with four membranes, of unequal dimensions, which are inclined to each other at different angles ; of these membranes three are lateral, and the fourth forms the base. The internal lateral membrane *b* lies almost parallel to the superior promontory of the os transversale *i*, from which it is separated by a channel, leading from the left to the right larynx.* Through this channel the air from the left bronchus must pass to reach the trachea. The internal lateral membrane has a free salient edge inferiorly, over which the air brushes in its passage from the lungs to the trachea.† The posterior, anterior, and lateral membranes are supported by bony rings, of which the anterior is the largest. The membrane forming the base is penetrated by the left bronchial tube, and is connected with several of the bronchial rings through the medium of the membrana tympaniformis. Thus the air from the lungs throws into vibration one large membrane in the right, and four in the left larynx, all of unequal dimensions, and constituting a very complex piece of mechanism.

In the *M. Merganser* or Goosander the inferior larynx is most developed on the left side *h* (*fig.* 916), which is chiefly membranous, while the other side *d* is composed principally of bone. On the left side there are four irregular membranes, *a*, *b*, *c*, supported

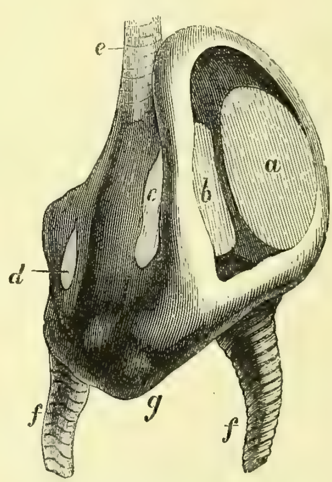
Fig. 915.



Two views of the Inferior Larynx of the Mergus Serrator.

by bones, and that on the external ring *h*. The os transversale is very small and does not reach the free edge of the internal membrane *b*, which is similar to that of the *Mergus serrator*, thus leaving a communication open between the right and left side of the cavity of the larynx, through which the air from the left lung must pass to reach the tube of the trachea, which terminates on the superior part of the right side of the larynx. The right side is chiefly surrounded by bone externally, having a very small oval membrane anteriorly, and is furnished with a small tympanic membrane at its junction with the bronchus. The salient portions of these membranes, and the small membrana tympaniformis are best adapted for putting the air into a state of vibration, reinforced by the chambers of which the larynx is composed.

Fig. 916



Inferior Larynx of the M. Merganser.

* The area of this channel is increased by an osseous cavity which is formed by the posterior concave surface of the ridge *g*, lying externally in front of the larynx.

† Beneath the inferior point of attachment of the internal lateral membrane, the above-mentioned conical osseous cavity passes vertically downwards *c* terminating between the bronchi in a kind of cul de sac.

In the female the larynx is of a much simpler structure, the external wall is composed of several consolidated rings, those situated below the os transversale terminating in the membrana tympaniformis between the last bone of the larynx and first of the bronchus.

In the *Anas clangula* we find another variety in the structure of the vocal organs. The inferior larynx is nearly of a semilunar form, with its convex surface directed exteriorly; it is situated obliquely to the axis of the trachea. It is partly bony, and partly membranous, and divided into several cavities. A large semilunar bone forms the principal framework of the whole larynx. On the left side there are two cavities, one of which is situated above the other. The superior cavity is formed by a groove in the semilunar bone by which it is bounded both externally and internally, but is furnished with a membrane above. At the posterior extremity of the bone forming the floor of this cavity, there is a perforation by which the air in the inferior cavity from the left bronchus is admitted. The inferior cavity lies at the base of the larynx, and is connected with both bronchial and tracheal apertures; it is bounded anteriorly by the semilunar bone, and inferiorly by the basilar membrane.

On the right side the semilunar bone forms externally a protuberance, which is concave within, forming the anterior and lateral boundary of a large cavity which lies between the bronchial and tracheal apertures. This cavity is subdivided by bone and membranes into two irregularly formed cul de sacs, which are nearly parallel to the axis of the trachea.

The os transversale is a very irregularly formed bone, as in the Mergansers, dividing the larynx into two unequal and unsymmetrical parts; its superior prominence, which is conical, penetrates the trachea nearly one-eighth of the entire length of that tube. The rings of the trachea here are no longer entire but divided anteriorly and posteriorly by a dense membrane, and in some places by osseous interposed substances, the whole being supported within by the os transversale. A basilar membrane supported by the semilunar bone, forms the floor of the larynx. This membrane is perforated by the bronchial tubes, and is connected with the bronchi by means of the membrana tympani. In the female, the left side of the larynx lies above the right, as does that of the male, and the base is likewise oblique to the axis of the trachea. The trachea of the male has an enlargement occupying about one-fourth of its length, its size being regulated by an additional pair of muscles, which draws the rings of that part either into an oblique, or into a nearly horizontal position.

The whole of this complicated mechanism is concerned in producing the tones peculiar to the *A. clangula.*

The *A. rufina*, or red-breasted whistling duck, presents another instance of laryngeal structure peculiar to itself; but our limits will not admit our giving its anatomy in detail: let it suffice therefore to mention, that its left cavity, which is largest, is chiefly membranous, whilst the right is almost entirely osseous, and somewhat resembles in external form the larynx of *Mergus Merganser. A. muscatus, A. Penelope*, or widgeon, and *A. Ægyptiaca*, have also bony enlargements of the inferior larynx; but the *Anser domesticus*, and the *Larus*, and *Ardea*, with some others amongst the Grallatores, are destitute of these enlarged cavities common in the order Anas. The organs of voice in the Palmipedes are, with a few exceptions, only provided with one pair of muscles.*

In the Gallinaceæ the structure of the inferior larynx is more uniform, simple, and symmetrical than in the Palmipedes. In the male *Phasianus gallus*, the common cock, this larynx is composed externally of two or three of the lower half rings of the trachea, connected in the inside with the os transversale both anteriorly and posteriorly, through the interposition of two triangular laminas given off by it, which are also connected with the bronchi. Between the rings of the larynx there is interposed a membrane which forms the side of the glottis externally. The inferior portion of the trachea is much compressed laterally. The inferior larynx of the pheasant does not differ materially in structure from that of the cock. In the partridge the os transversale is attached immediately to the last half ring of the larynx. In the Gallinaceæ, owing to the os transversale lying below the last semilunar rings of the larynx, the membranes on each side are immediately opposite to each other, so as to form the two sides of the glottis, and the larynx is not entirely a double reed as in the Sylviadæ, in which the membrana semilunaris forms with the membrana tympani the interior lips of the glottis, and divides the larynx into a double organ of voice. In this respect the structure of the larynx in the Gallinaceæ is intermediate between the parrots and the singing birds. The trachea being compressed laterally, and the glottis very straight, these, according to Cuvier, may be considered the causes of the acute sounds which these birds produce. They are provided with one pair of muscles. In the Indian pigeon, however, the sterno-tracheal muscles divide, and send a few fibres to the inferior larynx.

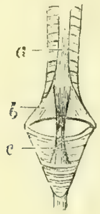
In the Falcons, the larynx being provided with but one pair of muscles, *viz.* the sterno-tracheal, its structure is much more simple than in the singing birds. The membrana tympani is however large, but does not appear to give off any semilunar membrane. The bronchial rings are distant from each other, and bound together by thin membranes; the rings of the larynx are almost in juxtaposition, leaving no vibratile membranous space between them; consequently the membrana tympani is the chief vibrating tissue. The order also has one pair of vocal muscles.

Scansores.—In the parrots the inferior

* The exceptions in this order are the *Velvet duck*, the *Golden Eye*, the *Red Breasted Merganser*, and *Ganet*, in which there are two pairs.

larynx differs in structure from that of any other order of birds. They have no os transversale dividing the vocal organs, which is consequently a *single* larynx. The segments of the rings in which the lower end of the trachea terminates are consolidated together on each side. The last two of these segments are of a crescent-like or semilunar form, with its axis nearly perpendicular to the axes of the ring of the trachea; they are concave to each other, and their extremities articulated together, forming an elliptical space which is furnished with a thin vibratile membrane, as seen in *fig.* 917. At their junction is the joint or axis on which they revolve upon each other, and by which the tension of the membrane of the glottis is capable of being varied.

Fig. 917.



Inferior Larynx of the Parrot.

a, *b*, tensors of the glottis; *c*, laxator of glottis.

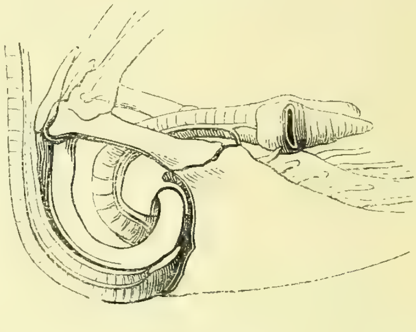
The glottis is formed on each side by the elastic membranes that fill the space between the semilunar bones; these membranes leave a narrow chink between them through which the air from the lungs passes, and puts them in a state of vibration whenever the bird draws them sufficiently tense; for this purpose they are provided with three pairs of muscles, of which two *a*, *b*, are tensors, and one *c* laxator of the glottis.

The trachea of birds comprehends that portion of the vocal tube which lies between the superior and inferior larynx; its diameter and length generally depend on the length of the neck of the bird. In the common crane, the trachea after making its exit from the thorax, penetrates the sterno-tracheal space, and then making four turns upon itself in the same plane, it leaves the breast bone to follow its course into the neck: by this arrangement the vocal tube is greatly lengthened for the purposes of voice, and the surface of the sternum increased for the attachment of the great pectoral muscles without adding materially to the weight of the bird. The voice of the crane is very sonorous, and may be heard at a great distance.

In Bewick's swan (*fig.* 918), the manner in which a considerable additional length is given to the trachea by its convolutions, will be evident upon an inspection of the figure.

The spoonbill presents another remarkable instance of convoluted trachea, doubling twice upon itself. Other examples of convoluted trachea are found in the Gallinaceæ; as in the *Rhynchæa Australis*, and *Phasianus Purraqua*. In the singing birds the trachea is a cylindrical tube; the rings which are at first cartilaginous become ossified with age. The tracheal rings, which are entire in the adult state, being connected by elastic membranes, are at a sufficient distance from each other to allow of all the movements of the neck.

Fig. 918.



Inferior Larynx and convoluted Trachea in Bewick's Swan, from Yarrell.

The diameter of the trachea in singing birds is nearly uniform and proportional to its length; but among the Palmipedes, the Mergansers, and some species of Anas, as the *A. fusca* and *A. rufina*, there are tracheal enlargements with additional muscles, to control their dimensions. The *number of rings* in the trachea of some birds is very great, surpassing that of any other class of animals. In the *Phœnicopterus*, according to Dr. Grant, there are at least 350 rings.

Physiology of the Voice of Birds. — The vocal apparatus of birds consists of the lungs, larynx, and trachea, representing a wind chest, reed, and pipe. The inferior larynx has been proved by Cuvier to be the organ in which the sounds are generated. To ascertain this fact, he divided the trachea of a blackbird about the middle of its length, thus preventing the passage of the air through the superior orifice; the bird notwithstanding continued to sing, though the tones were more feeble than before. In a second experiment on the pie, performed in the same manner, the bird cried with as great intensity of tone, and with the same acuteness as before the operation, for the space of about ten minutes when the blood from the wound being drawn into the larynx suffocated the animal. These experiments, however, were sufficient to prove that the sound did not arise from the superior larynx; and when we view the structure of that organ, and, find it destitute of vocal ligaments, or any salient membranous laminæ, and bounded by cartilaginous or osseous matter, and compare it with the complex organization of the inferior larynx, we might without experiments conclude the latter to be the organ of sound.

The superior larynx nevertheless performs an important office, both preventing the passage of the food into the wind-pipe, and modifying the sound of the voice. It can be opened and closed with rapidity, in singing birds; and is actively employed in the production of melody: we can easily witness its simultaneous movements with the mouth, in the song of the canary, linnets, and others. Its influence on the pitch is according to Savart, but little, not amounting to more than a semitone. The inferior larynx may be considered a reed prefixed to a tube. The salient laminæ of the membrana tympaniformis, and the membrana semilunaris are especially adapted to produce a series of vibrations, when a current of air is forced into the bronchi. It is indeed only necessary to dissect out the vocal tube of a bird, (such as that of the goose for example), and blow into it by the mouth, to elicit sounds. In the singing birds, which have the lower larynx furnished with the most elaborate muscular apparatus, the tension of the vibratile membrane of the glottis can be regulated with precision, so as to enable them to effect the varied melodies which nature or art dictates. In order to prove the duplex structure of the inferior larynx, Savart divided the recurrent nerve on one side in the living bird, after which it continued to sing with all the modifications of its melody as before. We agree as to the duplex office of the lower larynx in singing birds; but in them the semilunar membrane appears common to both sides, as is also the os transversale. Savart considered the semilunar membrane to be chiefly developed in those birds which have the most reedy quality of voice, the speaking birds for instance, such as the jays, pies, &c., but that, in the production of the flute tones in singing birds, it is more relaxed, and the glottis more open. He observes that, in making a transverse section of the trachea in the living bird, which also cuts the recurrent nerve, and produces a relaxed state of the glottis, the sounds become less '*criard*,' and less '*sourd*'; but, as birds thus maltreated suffer greatly, he recommends the section of the recurrent nerve only. It is one of the most difficult subjects in acoustics to determine theoretically the sound which many of the male Natatores ought to produce, such, for example, as the *Anas domesticus*, *A. clangula*, *Mergus serrator*, and *M. merganser*, the structure of whose larynges has been briefly described; and, when we consider that these larynges are composed of chambers of varied dimensions, bounded by walls partly membranous and partly osseous, the membranes being of unequal area, and perhaps unequal tension, we may have some notion of the extreme difficulty of the inquiry, when some of the greatest mathematicians of the past and present age have as yet been unable to determine analytically the law of the vibration of a single piece of stretched parchment, like the drum.

Experiment shows that a single membranous stretched disc will produce many other, besides its fundamental and harmonic sounds; we need not, therefore, be surprised at the discordant tones which many of the Natatores are well known to produce. The reason why short tubes, such as the tracheas of many small birds, produce tones of a very grave pitch, has already been satisfactorily explained by Savart. We observe, however, that, in those birds in which the trachea is shortest, the diameter smallest, and the walls very elastic, the voice is most acute. The muscles which vary the tension of the walls of the vocal pipe are in continual action during the modulation of the voice, in order to adjust the tube of the trachea to the pitch of the glottis; but the number of vibrations is doubtless determined by the glottis, and reinforced by the walls of the pipe, as in Mammalia. The cavities in the trachea of some of the Natatores must certainly influence the timbre, or quality of the voice of those birds. In the common crane, and other birds which have a convoluted trachea, the tones ought to be grave in proportion to its length, if the number of vibrations is determined by the length, as in musical instruments.

The voice of birds, as of other animals, is always in a minor key; but to describe the melody of each bird would be foreign to our subject. The range of notes is generally within an octave, though they can greatly exceed it. In the parrots, which have a voice of great power, the inferior larynx is single. The two membranes of the larynx leave a narrow chink between them, through which the air is forced from the lungs. These membranes, vibrating in all their dimensions, produce that harsh and disagreeable quality of sound peculiar to them. They can also whistle, during which the glottis is probably silent, and the column of air vibrates as in a flute, when a vibratory movement being communicated by the air, traverses the elastic walls of the tube. Besides the power of speech possessed by some birds, many can imitate almost every sound they hear. The blackbird has been known to imitate the song of the nightingale, the crowing of the common cock, and the cackle of the hen; the jay is said to mock the notes of the green-finch and the neighing of the horse so closely, that it was scarcely believed to be a bird by those who heard it; also the calling of fowls to their food, and the barking of the house dog.

The sounds uttered by birds are so various that to describe them physiologically in detail would occupy a volume; let it therefore suffice, in concluding this section of our article, to mention that the voice of birds has been made the theme not only of the naturalist, but also of numerous eminent writers both in prose and verse.

Voice of Reptiles. — The mechanism of the vocal organs in reptiles presents very diversified forms. The larynx varies considerably in structure, not only in different orders, but in different genera of the same family. It would therefore be impossible to compress within the limits assigned to this article the minute anatomy of the several species; they have been recently investigated and detailed in a monograph by Henlé.

Sauria.— In the *Crocodile* the larynx is composed of three cartilages, namely, the thyroid and cricoid consolidated into one ring-formed cartilage, called the thyro-cricoid, and the two arytenoid cartilages. The basi-hyoid element of the hyoid bone is expanded into a disc; and lies in front of the larynx, which it protects and supports. The arytenoid cartilages are connected with the superior margin of the thyro-cricoid by a membranous suture, but nothing approaching to a joint furnished with ligaments and synovial membrane is observable. The mucous membrane of the larynx is reflected over the inferior margins of the arytenoid cartilages, and forms a deep pouch beneath them, leaving a free fold with a margin on each side; so that, when these cartilages are brought near each other. this fold forms the vocal cord, and produces the tones peculiar to the *Alligators* In the *Cameleon* the larynx is provided with a sac in front, similar to that observed in some of the Quadrumana. The air passes to and from this sac by means of an opening, lying between the lower margin of the larynx and the first ring of the trachea. The larynx of this animal has been very minutely described by Treviranus.

Some reptiles have a membrane at the base of the tongue, which answers to the epiglottis; others have a cartilaginous epiglottis; others again a mere bony or cartilaginous processus epiglotticus, as in birds. "But," observes Henlé, "the presence of this process does not imply that there is no epiglottis, or conversely, the presence of an epiglottis that there is no processus epiglotticus." Cuvier described five cartilages in the larynx of the crocodile, but it is now generally admitted that he was mistaken.

The vocal cords are more perfectly developed in the *Gecko*, and the cameleon, than in the crocodile. They are broad membranous folds passing from the bases of the arytenoid cartilages to the inner surface of the crico-thyroid.

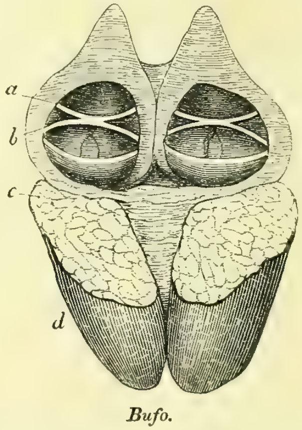
In the *Lacerta* a very thin membranous fold is found passing from the bases of these cartilages in the position of the vocal ligaments; but Henlé is of opinion that the acute chirping tone of the lizard depends rather on the vibration of the margins of the glottis, than on these folds, which are incapable of being approximated to each other, or brought into a state of tension.

Chelonia.—The vocal organs of the Chelonia are not adapted for perfect intonation of the breath, being destitute of vocal cords. The superior portion of the larynx is surrounded by, and connected with the basi-hyoid element of the os hyoides as in the Sauria. In the *Emys*, and the *Testudo*, the thyroid cartilage is annular, and distinct from the cricoid; the arytenoids are triangular, and the internal surface is much enlarged, owing to the very concave form of the larynx. In the *Midas*, the aditus laryngis is furnished with a fold of mucous membrane, which serves for the production of certain sounds. In the great tortoise of Madagascar, Cuvier describes a triangular membranous crest attached to the base of the larynx which, ascending to its opening, divides it into two parts, and is analogous to what is found in the superior larynx of some birds. Meckel found the same kind of crest in *T. tabulata*, but it is absent in *T. Græca* and several other species. The muscles of the larynx are the constrictor, and the dilator aditus laryngis.

Ophidia. — In this class the larynx is very little developed, with regard either to volume or to mechanism. The upper rings of the trachea are consolidated into a crico-thyroid cartilage, to which the arytenoids are attached. In some species these are sessile, mere processes of the crico-thyroid; and in others, they are divided from it by a suture, but in the pythons and boas they are free. The processus epiglotticus is nearly quadrangular in the *Boa:* the vocal cords are absent, and therefore the voice is reduced to a mere hissing sound, which is produced by the breath passing over the edges of the aditus laryngis. The muscles of the larynx are the elevator, depressor, dilator, and compressor laryngis.

Batrachia. — In the Batrachia the two arytenoid cartilages form a considerable portion of the frame of the larynx, and the cricoid, with a few exceptions, is a complete ring. The arytenoids are triangular, and their apices being upwards form the superior lateral boundaries of the larynx. The vocal cords pass from end to end of the bases of the triangles. According to Henlé, the whole of the tailless Batrachia, except the *Pipa* and the *Dactylethro*, have vocal cords. In *Bufo* there are two pairs of vocal cords (*fig.* 919), corresponding to the inferior vocal cords in Mammalia.

Fig. 919.



Bufo.

a, and *b*, semilunar folds of the superior vocal cord; *c*. inferior vocal cord; *d*, lung.

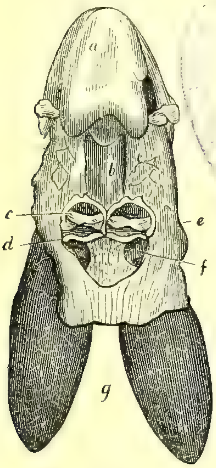
Above and below the vocal cords there are sacs lined with mucous membrane, and bounded by the arytenoid cartilages. Between the vocal cords a small cartilage is sometimes found.

In *Bombinator igneus, Hyla verrucosa*, and others, the arytenoid cartilages are regular obtuse-angled, and nearly equilateral triangles. In *B. cinereus* they are more acute-angled, and directed backwards. The vocal cords in bufo are very thin elastic membranes, such as might be expected to produce the croaking deep tones of these batrachia.

In *Pipa* the larynx is a very peculiar piece of mechanism; the arytenoid cartilages being convex externally and concave internally, so that when the entrance to the larynx is closed they form a dome over the windpipe, which Cuvier has compared to a kettle-drum.

In *Rana temporaria, R. esculenta*, and *Hyla*, the males are provided with two sacs, which open by a straight canal into the larynx. These sacs are situated on each side of the lower jaw, and are capable of considerable distension, when filled with air during the cry of the animal. Cuvier, Roesel, and Blumenbach, describe only one sac in Hyla; but Meckel, as well as Henlé and myself, found two sacs, as in the other frogs. These sacs doubtless exert a powerful influence on the quality of the sounds which frogs utter, analogous to the influence of similar sacs which exist in many of the higher animals.

Fig. 920.



Rana temporaria.

a, tongue; *b*, os hyoides; *c*, superior vocal cords; *d*, inferior vocal cords; *e*, pharynx; *f*, right bronchus.

The muscles acting on the larynx in Batrachia are the dilator aditus laryngis and the constrictor aditus. Besides these, there is found in the tailless Batrachia a third muscle, the compressor glottidis, which in Brito arises from the columella*, and is inserted into the posterior point of the arytenoid cartilage. Its use is to compress the larynx, to bend the posterior angle of the arytenoid outwards, and to expand the vocal ligament. It is the most important muscle connected with the voice in the tailless Batrachia. Its course varies in different species, and is absent altogether in Pipa.

* One of the inferior processes of the os hyoides.

In *Proteus anguinus* the most simple form of cartilaginous larynx is found, consisting of lateral cartilaginous strips, divided in two on each side; the superior portion answering to the arytenoid cartilage of the higher orders of animals, the inferior to the laryngo-trachealis cartilages.

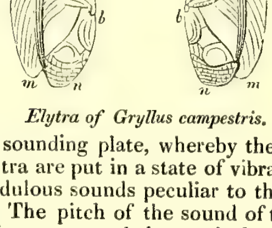
In the Triton, and Salamander, the larynx consists of a membranous sac, which is kept open by the lateral cartilages of the vocal tube. Hence we learn that the arytenoid cartilages do not wholly disappear, until the larynx becomes entirely membranous.

Insecta. — A large number of insects are mute; some produce their sounds merely by friction, and others by the passage of the air through the thoracic spiracles. The sounds produced by friction are denominated stridulation; those by the air from the tracheæ, buzzing, or humming (bourdonnement), &c. Organs adapted to produce stridulation are found in the Orthoptera, Omoptera, and some of the Coleoptera.

Grylli.—In the *Gryllus campestris* (*fig.* 921) the elytrum is composed of dry, thin, translucent membranes, forming two planes, united and strengthened at their junction by four longitudinal and parallel nervures; one of these planes lies on the back, and the other on the side of the insect. The former of these planes is divided by a series of regularly curved nervures, into a number of areoles. The musical apparatus may be divided into two systems, the first composed of four oblique nervures, which terminate in a strong nervure, serrated like a file (*a*); this may be considered as the bow. The second is formed of three nervures, which take their origin in a remarkable point in the internal border of the elytrum, furnished with a tuft of short stiff hairs, or brush (*b*); above this point is found a firm, transparent, and nearly triangular disc or sounding plate *, surrounded by a nervure. When the insect cries, the wings are crossed, and the bow rubbed rapidly across the whole length of the

Fig. 921.

1. 2.



Elytra of Gryllus campestris.

disc or sounding plate, whereby the whole of both elytra are put in a state of vibration, and the stridulous sounds peculiar to these grylli result. The pitch of the sound of the house cricket is very acute, being equivalent to about 4096 vibrations in a second.

Cicadæ, Cigales.— The Cicadæ have their musical instruments inclosed in the interior of the abdomen. Reaumur gives a detailed description, illustrated by drawings, by which they may readily be recognised. These instruments, he says, are contained in the abdo-

* Termed by M. Goureau the "chanterelle."

minal cavity, divided into two cells by a scaly partition of a triangular form, covered by two cartilaginous plates, acting as shutters or opercula. When viewed from the abdominal surface, each cell presents exteriorly a white folded membrane with radiated reflections, which he terms the mirror. On opening from the upper surface the part of the abdomen corresponding to the cavity, we perceive on each side a plaited membrane, dry and sonorous, which is moved by a powerful muscle, composed of straight parallel fibres springing from the scaly partition ; this membrane is the tymbal. In order to bring into play an instrument so complicated, Reaumur states that the insect alternately contracts and relaxes the muscle attached to the tymbal, and by this means produces the sound. He believes that "this sound is augmented in the drum, and that this portion of the vocal organ has no other use than to give it brilliancy." He also imagines "that the trochanter of the haunch performs the office of a curb, and prevents the operculum from being too much elevated during the song. Some doubts have arisen with regard to this simple explanation of the song of the Cicadæ, and entomologists have concluded that the air performs an important part in the formation of the voice, and that it is due, at least in a great measure, to a rapid current issuing from the stigmata of the metathorax, which resounds within the organs above described."

THE HUMMING, OR BUZZING OF INSECTS.— It has been supposed by some entomologists that the hum of insects is produced by the oscillations of their wings during flight, and this supposition is strengthened by the fact that the tones are altered during the suspension of the insects in the air, and that the sound becomes more acute when the tips of the wings are removed. This hypothesis will not, however, bear the test of rigid investigation.

It was observed by John Hunter, "that insects emitted sounds after their wings were cut off.* De Geer†, finding that after he had cut off the wings, winglets, and poisers, the buzzing continued, placed the insect under a microscope, and observing that the stumps of the wings were in rapid motion, he pulled them off by the roots, on which the buzzing ceased ; and hence he inferred that the sound was produced by the vibrations of the wings. But it is not surprising that insects, after such mutilation cease to emit any sound. Burmeister‡ is of opinion that the sounds of some Diptera, such as *Tabanus bovinus*, are produced by a stream of air rapidly transmitted through the thoracic air-holes during flight. He has described and figured the mechanism of the thorax and the air-holes of the *Eristalis tenax*, which is as follows : — The aperture of the hinder air-hole is provided with a sphincter muscle, perpendicular to the inner surface of which are sixteen or eighteen horny lamellæ, of the same breadth as the muscle, and connected in the middle by another longitudinal horny band. The sphincter muscle is lined with a membrane clothed with feathery hairs, which cover the air-hole like a sieve, and exclude foreign bodies. He leaves it to naturalists to decide whether or not this mechanism contributes to the formation of the sound ; adding that either way it is of little consequence, as many insects have no such lamellæ. He observes that when the insect sits or crawls it breathes through the air-holes of the abdomen, but during flight through those of the thorax. He considers the hum of insects to be in reality a whistle. The pitch of this hum is hitherto unexplained, although it is quite certain that it does not depend upon the number of the vibrations of the wings, for in a favourable light the motion of the wings of many insects, whose hum is of a high pitch, can be clearly detected; but, if that pitch were owing to the vibrations of the wings, their number would necessarily be so great as to render the motion imperceptible.*

* Phil. Trans. 1792. † Vol. ii. p. 13.
‡ Art xvi. p 377. Taylor's Scientific Memoirs.

The author has recently examined, with Professor Queekett, the spiracles of other insects, such as the blue-bottle fly, and the humble bee, and has discovered in them a beautifully organised valvular opening, capable of producing the sounds which these insects emit during flight.† In *fig.* 922. is shown one of the large thoracic spiracles of a blow fly (*Musca vomitoria*); it consists of two valves, one much larger than the other, each

Fig. 922.

Thoracic spiracle of the blow-fly, Musca vomitoria.

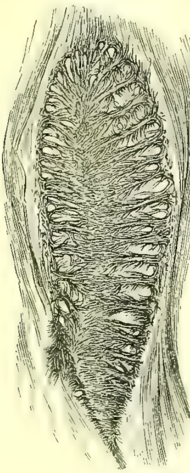
being provided with numerous branching horny filaments or hairs which serve as a support to the thin membrane forming the valve; a somewhat similar form of spiracle occurs in the humble bee, (*fig.* 923). The valves are nearly of equal size, and the branching hairs are much stronger and more numerous than those in the blow fly.

* Those who wish to pursue the subject further may consult the second note to p. 425. art. MOTION.,

† The pitch of the blue-bottle fly ranges, in different species, from 288 to 341 vibrations in a second.

Besides stridulation, and humming, some insects, such as bees, emit a cry, or, as the French entomologists term it, *piaulement*. M. Goureau supposes this variety of voice to be used, when bees swarm preparatory to their emigration. He remarks that those insects which produce the sound by friction are not singers, but musicians; and that insects in general make use of their voices to communicate certain ideas and sensations.

Fig. 923.



Thoracic spiracle of the Humble Bee (Bombus terrestris).

In insects we find a great diversity of beautifully contrived mechanism for the modulation of sound, all answering the same end in the economy of these countless myriads of minute beings.

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(*John Bishop.*)

WORMIANA OSSA (*vide* CRANIUM).

WRIST-JOINT (*Radio-carpal Articulation*), NORMAL ANATOMY OF THE. — The articulation of the wrist results from the union of the bones of the fore-arm with those of the hand, and is constituted by the contact of the lower surfaces of the radius and of the triangular interarticular cartilage with the scaphoid, lunar, and cuneiform bones of the carpus. The radius and the triangular fibro-cartilage accordingly present a uniformly smooth and slightly concave surface, whilst the first three bones of the carpus afford a surface which is as uniformly convex. The transverse measurement of these articular surfaces is greater than the antero-posterior, since the former averages one inch and a half in the adult male, whilst the latter scarcely exceeds three quarters of an inch.

In this joint are found all the anatomical dispositions which characterize other *arthrodial* articulations: the *bones* are invested with *cartilage*, lined by a *synovial membrane*, and present smooth surfaces which deviate but slightly from being planiform; and lastly, the *ligaments* connecting the osseous surfaces are so disposed, as to admit of all the free gliding motions which are indispensable to the hand as an organ of touch and of prehension.

It is proposed in this article to describe, seriatim, the different structures which enter into the composition of the radio-carpal articulation, with their relative anatomy, but for a detailed account of the *surgical anatomy* of the region of the wrist, the reader is referred to the article *Hand*, where this subject has been fully entered into.

I. *The Bones which constitute the wrist-joint.*

a. *The Radius.* — The lower end of the radius, which is of a quadrilateral form, is curved so as to present a concavity anteriorly, and a convexity in the opposite direction. On its different aspects various objects of interest present themselves to view, which may be thus enumerated: — *Anteriorly* is seen a smooth surface, to which the tendons of the flexor muscles, surrounded by their synovial sheath, are applied; *posteriorly*, a series of depressions and irregular elevations are observable, the former of which indicate the course of different tendons passing to the hand. Of these depressions the most external is a broad but shallow groove, which lodges the tendons of the radial extensors of the carpus: to its inner side, but separated from it by a well-marked ridge, is a narrow deep groove, which runs obliquely downwards and outwards, and transmits in this direction the tendon of the extensor secundi internodii pollicis. The remainder of the dorsal aspect of the radius is subjacent to the tendons of the m. extensor digitorum communis and the extensor indicis. The *outer surface* of the lower extremity of the radius is the least extensive, and is furnished with a shallow groove, which affords insertion to the tendon of the supinator longus, and gives passage to the tendons of two of the extensor muscles of the thumb, viz., the extensor ossis metacarpi pollicis and extensor primi internodii pollicis. This surface is terminated inferiorly by the *styloid process*, which lies on a plane a little posterior to the last-mentioned groove: lastly, the *inner* surface of this portion of the bone presents a smooth concave surface of oval form, its long axis directed from before backwards, which serves for articulation with the head of the ulna, and enters into the formation of the inferior radio-ulnar articulation. By its inferior surface, the radius is adapted for articulation with the carpus. The aspect of the surface, owing to the curvature of the radius already indicated, is downwards and forwards, whilst at the same time it is directed slightly inwards, from its external boundary passing lower than the internal.

The inferior surface of the radius presents a triangular outline, the apex of which is placed externally at the styloid process, whilst the base, in the opposite direction, is constituted by the sharp margin separating the inferior from the internal articular surface on the radius, and serving for the attachment of the broad extremity of the radio-ulnar interarticular cartilage (*triangular fibro cartilage*). The two margins which border this inferior articulating surface of the radius serve for the attachment of ligaments, and of these the anterior is the most prominent. Lastly, the carpal surface of the radius is divided into two portions by a ridge, which traverses it from before backwards: the external of these articular "facettes" is triangular in shape, and adapted to the scaphoid bone, whilst the more internal of the two is quadrilateral, and articulates with the semilunar carpal bone.

It has been mentioned that the radius at its lower extremity undergoes a change of form, and that from being cylindrical higher up, it becomes here quadrilateral. This expansion of its surface takes place at the expense of its solidity, for a section of the bone shows that inferiorly the compact tissue is extremely thin, whilst the cancellated tissue is in proportion more abundant.

This circumstance is adduced, as in some measure explaining the frequency of fracture in this situation, an accident notoriously common.

The ulna is excluded from the articulation of the wrist by the triangular fibro-cartilage, which stretches across transversely between the head of the ulna above and the carpus inferiorly, and presents a surface concave in each direction.

The inferior surface of this fibro-cartilage is on the same plane with the inferior surface of the radius, and constitutes with it the superior articulating surface of the wrist-joint. The entire of this conjoint surface is somewhat oval (or diamond-shaped), and is limited externally and internally by the styloid processes of the radius and ulna respectively.

b. *The Scaphoid, Semilunar, and Cuneiform Bones of the Carpus.* — The *Carpus*, superiorly, presents a surface which is pretty uniformly convex. That convexity, however, is slightly interrupted by the undulating lines resulting from the lateral articulations between the bones which compose it.

The convexity of the upper surface of the *scaphoid bone* is triangular in form, and articulates with the outer facette on the inferior surface of the radius; the *semilunar bone* is quadrilateral in conformity with the shape of the inner facette of the radius, whilst the *cuneiform bone* presents a surface of a triangular form, by which it comes accurately into apposition with the inferior surface of the radio-ulnar interarticular cartilage. The aspect of the radial or upper conjoint surface of those three bones is directed upwards and slightly backwards.

II. *The Ligaments.* — These are placed on each of the several aspects of the wrist, and are usually designated from their position,— the anterior, the posterior, and the lateral radio-carpal ligaments. But whilst the wrist-joint is thus protected on its different aspects by ligamentous bands, it is to be observed that no distinct intervals naturally separate these ligaments from one another, so that it might with strict propriety be said that the articulation of the wrist is defended by a ligamentous envelope of a capsular form, strengthened in particular parts, but more especially laterally by other superimposed and superadded fibres.

a. *Anterior Radio-carpal Ligament.* — The fibres of this ligament are connected superiorly to the anterior margin of the lower end of the radius and of its styloid process, and to the "triangular ligament," from whence they radiate to their insertion into the anterior surfaces of the scaphoid, semilunar, and cuneiform bones. *Below*, they are partly continuous with the fibrous fasciculi (*interosseous ligament*), which connect the two rows of carpal bones.

The fibres of the anterior radio-carpal ligament pursue a direction for the most part downwards and inwards.

By its anterior surface this ligament is in relation with the tendons of the deep flexor muscles, and also (but more remotely), with those of the superficial flexor, and with the median nerve, the entire surrounded by an extensive and complicated synovial apparatus. Beneath these structures, and immediately in front of the ligament, is the anastomosis, between the anterior radial and the anterior ulnar *carpal arteries*, which also receive tributaries from the descending branches of the interosseal, and the ascending of the deep palmar arch of arteries.

b. *Posterior Radio-carpal Ligament.*—This ligament much resembles the one last described. Arising from the posterior edge of the carpal end of the radius, its fibres pass downwards and inwards to the back of the carpus, where they expand and take an extensive attachment to the three inner bones of the first range. The tendons of the extensor muscles of the fingers are related to the superficial surface of this ligament, which has also in contact with it the posterior carpal arteries from the radial and ulnar trunks.

The anterior and posterior ligaments are connected, both externally and internally, with the lateral ligaments, so that no portion of the periphery of the articulation is devoid of ligamentous covering

c. *External Lateral Ligament of the Wrist-Joint.*—The external lateral ligament is funicular in form, and connects the styloid process of the radius with the scaphoid and trapezium, the two most external of the carpal bones. The direction of its fibres is downwards and backwards. The radial artery crosses obliquely over the external surface of this ligament, and separates it from the tendons of the extensor ossis metacarpi and the extensor primi internodii pollicis. The synovial membrane lines its inner surface. When the hand is fully adducted, this ligament is put upon the stretch.

d. *The internal lateral ligament.*—This ligament is larger and longer than the preceding; for, notwithstanding the greater length of its styloid process, the ulna is more widely separated from the carpus than is the radius. This ligament connects the styloid process of the ulna with the cuneiform bone, giving a fasciculus to the fusiform bone and to the anterior annular ligament. The tendon of the extensor carpi ulnaris is posterior and parallel to this ligament. The internal lateral ligament limits abduction, so as to render it the least extensive of all the motions enjoyed by the wrist joint.

III. *Synovial Membrane.* — The synovial membrane of the wrist joint is very extensive, and contains a large quantity of synovia. Its anatomical disposition is so simple as not to require any special notice; but it may be of practical importance to remember the proximity of this structure to the synovial sacs between the lateral articulations of the carpal bones, and also its contiguity to the articulation between the trapezium and the first metacarpal bone. The former circumstance explains the facility with which acute inflammation, occurring in the smaller carpal articulations as the result of imparonychia, may be propagated to the contiguous wrist joint, where, too frequently, the morbid action thus excited proves destructive to the articulation. The latter circumstance demands our attention, since it teaches that, in amputating at the first carpo-metacarpal articulation a careless use of the knife may inflict a wound upon the wrist joint itself, from which the most serious consequences may accrue.

The synovial membrane of the wrist joint is separated from that of the inferior radio-ulnar articulation by the triangular interarticular cartilage. In amputating at the wrist joint, if care be taken to leave the interarticular cartilage uninjured, the motions of pronation and of supination will be left to the forearm, and may therefore be communicated to the artificial substitute for the amputated hand. In this respect, the amputation through the joint offers an advantage which is sacrificed when amputation is performed through the continuity of the bones of the forearm.

IV. *Mechanical Functions.* — The wrist-joint enjoys every variety of motion included under the head of *gliding motions* (Bichat); thus it is capable of *flexion*, *extension*, *adduction*, *abduction*, and *circumduction*. In the motions of *flexion* and of *extension*, the carpus rolls either forwards or backwards on the lower articular surface of the radius. *Flexion* is limited, not only by the posterior ligament, but also by the lateral ligaments which are attached behind the centre of motion of the articulation. *Extension* is limited by the anterior ligament only. In *adduction* and *abduction* the carpal bones glide from side to side on the surface opposed to them. Of these motions abduction is the more limited, because, probably, the styloid process of the radius and the trapezium come sooner into mutual contact than the corresponding parts at the inner side of the joint do. In *circumduction* (a motion compounded of all the preceding ones), the hand moves through a circle representing the base of a hollow cone, the apex of which is at the joint. The free gliding of the carpal bones on each other causes this movement to appear more extensive than it is in reality, whilst it gives all that ease and grace to the movements of the wrist which are in so especial a manner its characteristics.

The wrist joint thus constituted would not, *à priori*, be supposed to enjoy that remarkable immunity from accidental luxation which must be conceded to it. In truth, this articulation owes its remarkable strength and its freedom from accidental displacements to the mass of tendons which occupy its anterior and posterior surfaces principally, not to its ligamentous connections, nor to the form of its osseous surfaces. Those tendons, like so many *vital ligaments* kept tense as well by the tonic as by the active contraction of their muscles, and bound down by the annular ligaments, bear off, in a great degree, all violent shocks from the joint itself, whilst, by their antagonistic resistance to each other, they at the same time maintain the bones in accurate contact.

But whilst, owing to these circumstances, the impetus of shocks applied to the hand are borne off from the articulation of the wrist, they fall in many instances with resistless force upon the lower end of the radius, which, owing to the thinness of its compact tissue, is ill adapted for opposing an effectual resistance. It has already been shown that the ulna is but *indirectly* connected with the carpus; and that a layer of highly-elastic tissue intervenes between the carpus and that bone. These circumstances taken in connection with the remarkable mobility of the lower radio-ulnar articulation sufficiently explain why the ulna so frequently escapes injury from forces which act on the hand, and which suffice to fracture the radius. At the same time it is to be observed, that displacements of the lower extremity of the ulna are by no means unfrequent accompaniments of fractures of the radius.

(*Benjamin Geo. M'Dowel.*)

WRIST, Abnormal Conditions of. — In the following account of the abnormal condition of the different structures which enter into the composition of the wrist, we shall consider this region as formed not only by the lower extremities of the bones of the forearm and the wrist-joint, properly so called, but also by the carpus surrounded by its fibrous and fibro-synovial tissues.

The abnormal condition of the different structures of this region may be arranged under those which we can refer—1st, to congenital malformation; 2nd, to accident; and 3rd, to disease.

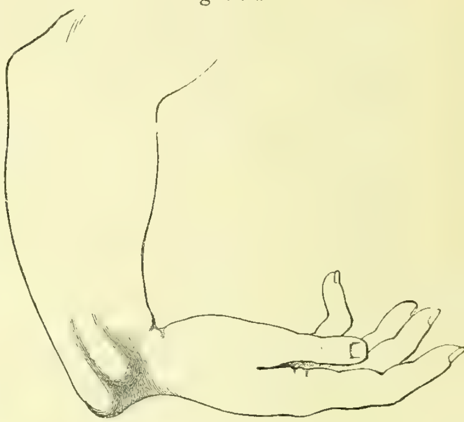
Congenital. — Congenital dislocation of the bones which constitute the radio-carpal articulation may be considered rare; nevertheless, I have seen within these few years thirteen examples of this malformation. One, in which the bones of the forearm were thrown forwards and the carpus backwards. In the remaining twelve cases, the bones of the forearm were placed on the dorsum of the carpus, which they overlapped.

The history of congenital luxations of the wrist-joint is modern. Cruveilhier, in his Pathological Anatomy (liv. ix., 1833), has published an example of this deformity, although he was not himself aware of the true nature of the case. The example he adduces is that of an adult female, concerning whose history, unfortunately, he could learn nothing. In this case the forearm was preternaturally short, and it formed a right-angle with the hand, which besides was inclined to the radial side of the forearm; extension was *impossible;* flexion, to a certain degree, was permitted; the inferior extremities of the radius and ulna were dislocated backwards, and formed a very considerable prominence beneath the skin posteriorly.

The extremity of the radius was less *salient*, and descended *much less* than that of the ulna. The superior extremity of the carpus could be felt on a plane which was superior and anterior to that of the inferior extremity of the bones of the forearm.

Dissection. — The bones of the carpus were found *on dissection* to be in a state of atrophy, and more or less malformed; the radius, shortened and deformed, scarcely measured five inches; the deformity principally affected its lower extremity, which was large and deeply grooved posteriorly for the reception of the tendons of the extensor muscles; the articular surface for the carpus was placed on the anterior aspect of the bone; the ulna was only six inches and a half in length, its lower extremity, much smaller than normal, descended half an inch below the carpal extremity of the radius.

Fig. 924.



Forearm, Cruveilhier's case.

The carpus was much deformed, particularly as to the first row, which was merely, we may say, in a rudimentary state. The pisiform was the only bone of this first range that was normal. The bones of the second or metacarpal row participated in the deformity. The head of the *os magnum* was altogether absent, and the unciform was imperfect.

Cruveilhier published the foregoing case, erroneously supposing it an example of dislocation of the wrist-joint, the result of accident. Dupuytren and Marjolin disagreed with Cruveilhier, but equally mistook the true nature of this case; they, doubting the possibility of an accidental luxation of the wrist-joint, considered that all the phenomena which the *post-mortem* examination of the limb presented in Cruveilhier's example, might be accounted for by supposing the case to have been one of fracture of the radius, and consecutive displacement of the ulna.

It must ever appear as a matter of surprise that Cruveilhier could have supposed that this case just adduced was an old accidental luxation left unreduced, because, according to such an hypothesis, neither the arrest of development as to the length of the forearm (which only measured six inches and a half), nor the abnormal appearances observed in the bones of the carpus, could have been satisfactorily accounted for, or explained.

It is equally difficult to imagine how it was that Dupuytren, who had his attention so much alive to the subject of congenital luxations, should have overlooked the true nature of Cruveilhier's case, and referred the phenomena it presented to the circumstance of the radius having been broken through its lower epiphysis; no one ever heard of shortening of the radius to this amount as the result of fracture; besides, the bones on the carpus were in a state of atrophy, and the ulna, which Dupuytren did not suppose had been fractured, was deformed, and only six inches and a half long.

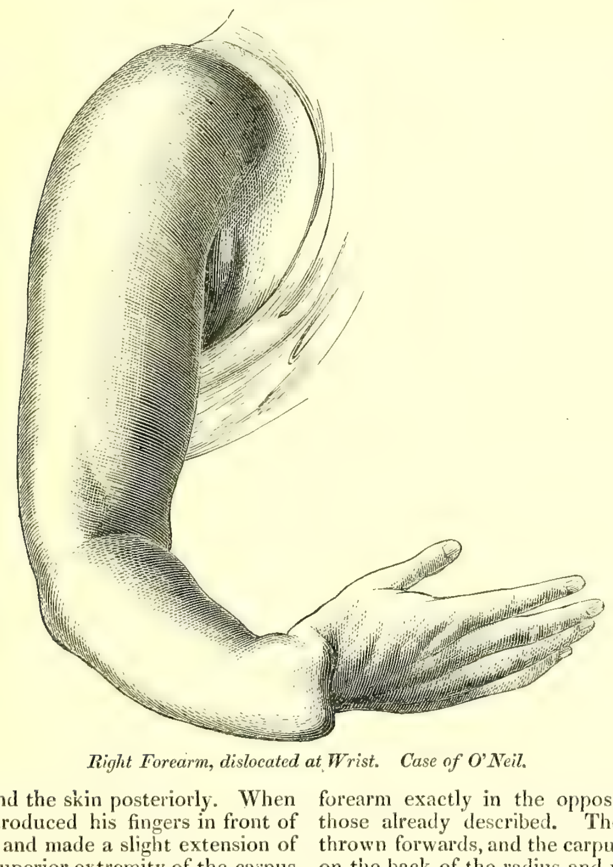
At the period when this case, the subject of so much difference of opinion between two such eminent pathologists, attracted the attention of the profession in Dublin, the writer had under his care, in the House of Industry, a patient who was born with deformity of *both* her wrist-joints and forearms, but whose right wrist-joint presented appearances closely resembling those described as characterising the deformity of the wrist and forearm in Cruveilhier's case. As the history of this woman's case was known from her birth, it was calculated to throw light on the subject in dispute. It seemed on this and other accounts so interesting, that on the 15th of December, 1838, I laid it before the Pathological Society in Dublin. It was as follows: —

Case II. — Deborah O'Neil, aged thirty, has been an inmate of the House of Industry, for the last seventeen years. She is liable to occasional attacks of epilepsy. She cannot be said to be insane, but she is wayward and refractory, and will not submit to any rational control. Yet she is very industrious. Her upper arms and hands bear in size and length a just proportion to the rest of her stature, which is about the middle size, but her forearms appear scarcely more than half their normal length.

Her left forearm is dislocated forward at the radio-carpal joint, while the right forearm is dislocated, as in the preceding figure, backward on the dorsum of the carpus.

The lower extremities of the bones of the right forearm could be seen and felt on the dorsum of the carpus, where they formed a very remarkable projection. The lowest extremity of the ulna could be seen to descend below the level of the lowest extremity of the dislocated radius, and when the hand of the patient was flexed could be made very prominently to distend the skin posteriorly. When the surgeon introduced his fingers in front of the wrist-joint, and made a slight extension of the hand, the superior extremity of the carpus could be felt to be placed superiorly and anteriorly to the lowest extremities of the bones of the forearm. The hand inclined to the radial side, it could be extended on the forearm freely, but flexion was incomplete.

Fig. 925.



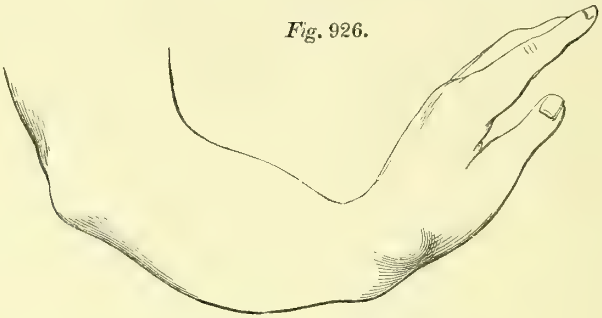
Right Forearm, dislocated at Wrist. Case of O'Neil.

The left wrist-joint presented an unique example of dislocation of the bones of the forearm exactly in the opposite direction to those already described. The forearm was thrown forwards, and the carpus with the hand on the back of the radius and ulna (*fig.* 926.).

This woman presented a very grotesque appearance in consequence of the remarkable shortness of both her forearms (*figs.* 926. and 927.); still she had a very good use of her hands, and showed admirable dexterity and skill in cutting out minute patterns on paper with her scissors.

As to this case of Deborah O'Neil, no ambiguity existed. At the time the writer thus laid her case before the meeting, accompanied by casts of her forearms, she was, and had been for many years previously, an inmate in the House of Industry, under the constant observation of the whole medical staff of the institution. The history of her life was known.

Fig. 926.



Left Forearm. Case of O'Neil.

It was stated that she never met with any accident, and that the peculiar deformity observable in each forearm and wrist-joint had existed from her birth.

The writer, in continuation, observed, that while congenital malformation was known very frequently to affect *simultaneously both* sides of the body, yet it would, on the other hand, be very difficult for any one to suggest what probable accidental causes could be imagined capable of dislocating the bones of both wrist-joints, in opposite directions, as in the case of O'Neil: besides, the mere displacement of the bones of both forearms at the wrist-joint, constituted only a part of the abnormal state of things noticed, because *both* of the forearms were so *short* as to measure only half the length of the arm, and did not exceed in length the measurement of the long axis of the hand. The history of her case, then, from her birth — the negative evidence as to the existence of any previous accidental cause adequate to account for the appearances, and the actual abnormal condition of *both* the upper extremities of O'Neil — all taken together, sufficiently proved her case to offer a curious specimen of congenital malformation of both wrist-joints and forearms."

When the writer presented this case to the meeting of the Pathological Society, he laid before the members two casts of the malformed extremities of the patient, and when the drawing of Cruveilhier's case (*pl.* 2. liv. ix.), was placed along side of the cast of the right forearm of O'Neil, every one present agreed in the opinion that the cast presented an exact counter-part of Cruveilhier's drawing (*fig.* 924.).

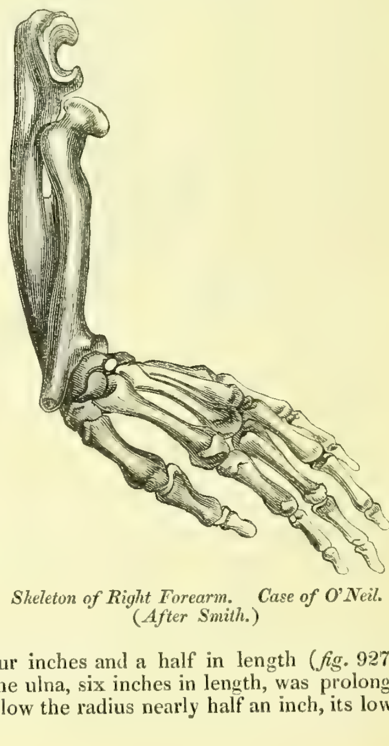
Deborah O'Neil, five years subsequently to this date, died suddenly of apoplexy, in the Government Asylum, Island Bridge. Dr. R. W. Smith, the surgeon of the institution, made a *post mortem* examination of the affected articulations. The result fully proved, as had been anticipated, that her right wrist-joint in every respect resembled the remarkable case brought forward by Cruveilhier.

Post Mortem Examination.—Upon the 15th of December, 1843, Mr. Smith exhibited before a meeting of the Dublin Pathological Society, the skeleton of the limb in this case.

The right extremity presented an example of luxation of the carpus forwards, while in the left was afforded an instance of displacement of the carpus *backwards*.

Right Extremity. — The upper arm and hand, as already mentioned, bore a just proportion to each other, and to the stature of the individual, but the forearms were scarcely one half the usual length. The first range of the carpus was articulated with the anterior aspect of the radius, which bone was only

Fig. 927.



Skeleton of Right Forearm. Case of O'Neil.
(After Smith.)

four inches and a half in length (*fig.* 927.). The ulna, six inches in length, was prolonged below the radius nearly half an inch, its lower extremity was destitute of the rounded head, which in the normal state is received into the concavity of the radius, and was carried forwards outwards and upwards (see *fig.* 927.). About half an inch above the level of its lower extremity it was in contact with the radius by a very small surface which was destitute of cartilage. An anterior and posterior ligament connected the two bones in this situation, and permitted a very slight degree of motion between them. The lower extremity of the radius was totally destitute of articulating surface, and was represented by a rounded and blunt margin.

The surface for articulation with the carpus was placed altogether on the anterior aspect of the bone. It consisted of a deep excavation of an oblong form, and its longest diameter running somewhat transversely; it was tolerably smooth, though not invested with cartilage.

The radius and ulna were not only remarkably short, but likewise atrophied, both as to breadth and thickness.

Their superior extremities, with the exception of being unusually small, presented no abnormal appearance.

The bones of the first row of the carpus were in a state of atrophy, especially the semi-lunar bone. When the hand was flexed at a right angle with the forearm, the lower end of the ulna formed a most conspicuous projection, while during extension, two prominences were seen; one, in front, caused by the carpus, the other posteriorly, marking the position of the lower extremities of the bones of the forearm. The hand was inclined to the radial side of the forearm; it admitted of being flexed to a right angle, and could be extended perfectly. The extensor tendons in their passage from the forearm to the hand were lodged in deep and narrow grooves, or channels, formed on the dorsal aspect of the *radius.*

Upon the left side the deformity was equally remarkable, although the reverse of that noticed on the right side. The carpus was received into a socket formed for it by the radius and ulna. This socket was not at the lowest extremity of the bones of the forearm but near to it, and on the dorsal aspect of the bones, and it presented somewhat a glenoid shape, the longest diameter of which was directed obliquely downwards and inwards. With respect to the carpus, there was neither a scaphoid nor semi-lunar bone. The hand placed in the state of extension formed a right angle with the forearm, but the patient had the power of bringing it to a straight line with the latter, in which position two prominences were seen; but, contrary to what was observed on the opposite side, the dorsal projection was here formed by the carpus, the extremities of the radius and ulna constituting the palmar eminences (see *fig.* 927.). In this left extremity, the carpus and forearm, including the elbow joint, were malformed, as well as the wrist-joint, but the rest of the skeleton, with the exception of the right wrist-joint and forearm, was quite normal.

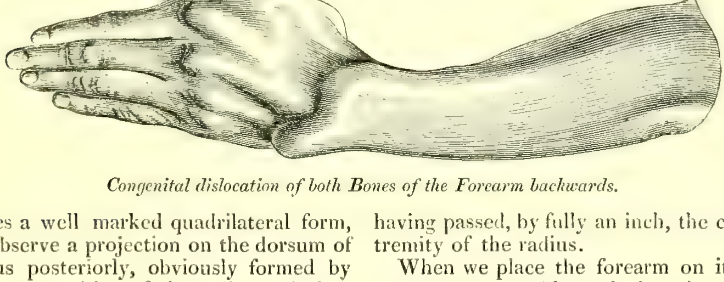
Case III. — Case of congenital luxation of the wrist-joint of *both bones* of the left forearm backwards.

The writer exhibited to a meeting of the Surgical Society of Dublin, on March 20th, 1847, the cast of the left forearm of an adult female, who had been born with a luxation of the carpal extremity of both the bones of the left forearm *backwards.* The lower extremities of the radius and ulna were placed completely on the dorsum of the carpus, while the hand was, consequently, situated in the front of these bones.

This remarkable cast of congenital luxation of the wrist-joint was sent across the Atlantic by Dr. R. MacDonnell, now holding, as a surgeon of the Montreal Hospital, a distinguished place in British America.

We observe that in the casts (*figs.* 928. and 929., the representations of Dr. R. MacDonnell's case), the hand is well formed, but that the forearm is *much shorter* than it should be, being very little longer than the hand; the whole length of the forearm is not eight inches, while that of the hand, measured in its greatest length, amounts to six inches and one half. The forearm in its upper part is round and muscular; as we examine it towards the hand,

Fig. 928.



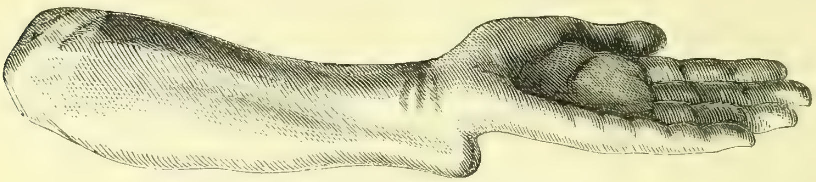
Congenital dislocation of both Bones of the Forearm backwards.

it assumes a well marked quadrilateral form, and we observe a projection on the dorsum of the carpus posteriorly, obviously formed by the lower extremities of the radius and ulna, which are dislocated backwards. The lower extremity of the forearm at the wrist here exhibits a very oblique termination, the ulna having passed, by fully an inch, the carpal extremity of the radius.

When we place the forearm on its palmar aspect, as on a table, and view the ulnar side of it, we notice that the ulna rides conspicuously on the back of the carpus, being above its level about an inch; and at the same time that the ulna has passed so far downwards on the back of the carpus as to reach even to the upper extremity of the metacarpal bone of the little finger (see *fig.* 929.). The radius at its lowest part, besides being thus shorter than the ulna, is much less salient on the dorsum of the carpus.

The upper extremity of the carpus and the hand are placed, as has been mentioned, anteriorly to, and somewhat above, the lowest extremity of the radius and ulna, and consequently the measurement of the antero-posterior diameter of the wrist is much increased; the whole forearm is somewhat bowed, presenting on its anterior aspect a concavity in the longitudinal direction. Near the wrist-joint the tendons of the flexor carpi ulnaris on the inner side, and of the flexor carpi radialis on the outer, or radial side, are thrown into strong relief, and thus contribute to give the quadrilateral form to the wrist above alluded to.

Fig. 929.



Second view of the same deformity as Fig. 928.

Since the writer made this communication to the Surgical Society of Dublin, he has seen other cases of congenital luxation at the wrist-joint of both the bones of the forearm backwards on the dorsum of the carpus. They so strongly resembled the cases just now adduced, that he refrains from entering into particulars. From all these last mentioned, the individuals practically suffered little from the defect.

From the cases the writer has seen or investigated, he may draw the following conclusions: —

1st. That the case of D. O'Neil, brought before the Pathological Society of Dublin, Dec. 15th, 1838, by the writer, was the first example laid before the profession with the intention of proving that such a lesion as a congenital luxation of the wrist-joint existed.

2nd. That Cruveilhier's case, adduced five years previously, as a case of an old unreduced luxation of the wrist-joint, and considered by Dupuytren as a fracture of the radius and dislocation of the ulna, and since misinterpreted by others, must hereafter be looked upon as an excellent example of congenital luxation of both the bones of the forearm backwards at the wrist-joint.

3rd. That the case sent to Dublin by Dr. MacDonnell of Montreal, is another example of a congenital luxation of the bones of the fore-arm at the wrist-joint backwards.

4th. In these three the humerus and hand seem to have borne, as to length and size, a normal proportion to the stature of the individuals; but the forearms in all three were so much shortened, as not to exceed by one inch the measurement of the long axis of the hand.

5th. The lower extremity of the ulna in the three cases, instead of being on a level with the lower extremity of the radius, as it normally is, had passed lower down on the dorsum of the carpus from half an inch to one inch.

Besides these three cases of congenital luxation of the bones of the forearm backward at the wrist-joint, Dr. R. Smith has, in his valuable work recently published, referred to two more specimens of the same malformation. A cast of one of these specimens was preserved in the Museum of the Bristol Infirmary, in August, 1836, when the writer and Dr. Smith visited that hospital, and the bones of the other specimen have been preserved in the Museum of the Richmond Hospital.

The case of O'Neil presented in her left forearm the only example of which we have heard of congenital luxation of the bones of the forearm forwards (*fig.* 926.). In this case, also, it is to be remarked, that the forearm was preternaturally short.

Since the above observations were written I have seen other examples of congenital luxations of the wrist, in which the bones of the forearm were displaced backwards, and the carpus forwards, as in *figs.* 924. and 925. Sometimes the defect was single, or only affected one forearm; in others, the defect, if the paradoxical language be allowed, was symmetrical, affecting both wrists alike. A case of this last description was shown to me lately in the Downpatrick Infirmary, by the surgeon of the institution, Mr. Brabazon, who was kind enough to present me with a cast, which I have in my possession.* This healthy young woman is the mother of many well-formed children, and feels but little inconvenience from the malformation.

When speaking of the congenital defects of the elbow-joint, we noticed that the upper extremity of the radius often exceeded its normal length, so as to reach as high as the level of the olecranon process. (See ELBOW, Abnormal Condition of.) We may here remark, that the ulna as the result of congenital malformation, in almost all the specimens we have examined, of the congenital

* This cast so much resembles that of *fig.* 929., that they could scarcely be supposed to have been taken from two different individuals.

luxation of the wrist, has been at least half an inch lower down than the level of the carpal extremity of the radius. The reverse, however, of this I have lately seen, in a case of congenital luxation of the wrist, under Dr. M'Dowel's care, in the Whitworth Hospital. In this case, of which Dr. Gordon has been kind enough to present me with a cast, the radius has, at its lower extremity, passed half an inch lower down on the back of the carpus than the ulna; varieties have been also noticed as to the carpus; in some cases the bones of the carpus were not only malformed, but deficient in number; in one case nine bones were found.

There are other congenital malformations of the wrist-joint which demand some attention from the physician and surgeon, such as affections of the wrist analogous to valgus, and cases of the foot and ankle, but we do not consider this the place to discuss these cases.

We may make the same remark as to those congenital defects of the hand with deformity of the wrist, which have been noticed to coincide with a deficiency in the brain on the side opposite to the deformity.

ACCIDENT. — The principal lesions which the structure that compose the region of the wrist are liable to, are: —

1st. Dislocations of the wrist and neighbouring radio-ulnar articulations.

2nd. Dislocations of the bones of the carpus.

3rd. Fractures of the lower extremities of the bones of the forearm, in the immediate vicinity of the wrist-joint.

1st. *Dislocations.* — Dislocations and fractures of the bones entering into the composition of the wrist-joint are two kinds of lesions, which for a long time have been confounded together, or mistaken for each other. Even in modern times authors have stated the wrist-joint to be liable to numerous luxations. Thus, Boyer, Petit, Mr. Samuel Cooper, &c. &c., entered into a description of the different dislocations of the wrist, as *forwards*, *backwards*, *inwards*, and *outwards*, *complete* and *incomplete*, just as Hippocrates and others, down to Celsus, had done.

Nevertheless, some moderns, at the head of whom we would place Dr. Colles of Dublin, Dupuytren, and Sir Benjamin Brodie, maintained that luxations of the wrist-joint from accident were either *impossible*, or, at all events, *exceedingly rare*, and expressed their opinion that authors had, under the erroneous name of dislocation, really described an accident now pretty generally believed to be a fracture of the radius in the immediate vicinity of the wrist-joint, with displacement backwards of the carpus and hand.

Velpeau followed these, and not only denied the reality of such an accident as simple dislocation of the wrist, but gave his reasons why he believed that no such accident could occur, observing, that the strong tendons of the flexor muscles of the forearm, bound down by the anterior annular ligament of the carpus, must render impossible any luxation of the bones of the forearm forwards at the wrist-joint, during any forcible bending backwards of the hand, such as might, for example, be produced by a fall on the palm; and, 2ndly, that the common and radial extensor (restrained as they are by the posterior annular ligament), oppose any luxation of the bones of the forearm backwards at the wrist during a movement which should produce an extreme flexion of the hand forwards.

Velpeau, however, admitted, that from experiments he had made on the dead subject, he had learned that efforts of a different order, such as a forcible pulling, accompanied with a simultaneous bending of the hand, whether backwards or forwards, inwards or outwards, might break every tissue, and produce a luxation without any fracture of the radius. Such cases, he says, he believes will always be accompanied with a wound of the integuments, and are not to be looked upon as the simple dislocations we are now considering, nor should they, in his opinion, enter into the same category with them.

In support of the doctrine, that most, if not all, of the simple dislocations of the wrist, of the authors already alluded to, were really fractures of the lower extremity of the radius, we confess that one observation of Velpeau appears particularly strong, viz., that for the last thirty or forty years in which the question has been discussed, and the reality of the luxation disputed, no one has brought forward one instance which, rigidly examined, he would look upon as an incontestable example of a *simple* luxation of the wrist-joint. He admits that the solitary case adduced by Voillemier is a very notable one, and deserving of attention, but that in his opinion, the question is still open as to whether a simple luxation of the wrist-joint can occur, without there being at the same time any lesion of the edges of the articular surfaces, or of the integuments.

We think we cannot do better than here give an abstract of this remarkable case, given by Voillemier.*

"Levillain Louis, æt. 27, of a vigorous constitution, on the 28th Sept. 1839, was admitted under the care of M. le Noris, into the Hôpital des Cliniques (Paris); at the moment of admission he was in a hopeless state, completely insensible; the pupils largely dilated, the respiration stertorous. Amongst other lesions from which the patient had suffered, in consequence of his having fallen into a court-yard from a window three stories high, to the ground, it was noticed specially *that the left wrist-joint presented a very remarkable deformity*, and of such a nature that Voillemier, prejudiced as he said he felt he was, that a luxation of the wrist was a great rarity, if not an impossibility, could not help saying to his colleague, M. Dumeril, present at the examination of the patient, that the case be-

* See Archives Générales de Médecine, Decemb. 1839, p. 400.

fore them was one of dislocation of the wrist. Four hours after the admission of the patient into hospital he died.

"The forearm was semi-flexed as well as the hand. The bony plane represented by the metacarpus and the carpus was almost parallel to that of the forearm. The hand was neither adducted nor abduced, but had suffered a displacement "de totalité" towards the internal side. At the posterior and inferior part of the forearm there was a saliency formed by the displaced carpus. *A line drawn from the summit of this saliency to the phalangeal extremity of the metacarpal bone to the middle finger, measured three inches and seven lines, the same length which the uninjured carpus and metacarpus of the opposite side presented.* At the inferior and anterior part of the forearm A, there existed a transverse eminence, situated about eight lines nearer to the extreme point of the fingers, than the posterior saliency B, while it projected anteriorly beyond the plane of the palmar surface of the hand, fully seven lines. The radii on both sides measured alike. The skin was abraded, and a wound about an inch long existed on the dorsal surface of the radius near the wrist, at about the level of the superior border of the pronator quadratus.

Ligaments.— The external lateral ligament and the posterior ligament were lacerated; the anterior completely torn from the border of the radius. Some remnants of this structure lay on the front of the carpus. The internal lateral ligament was not torn, but the styloid process of the ulna, maintained by this ligament, and at the same time by the attachment of the sheath of the flexor carpi ulnaris, had been detached from the body of the bone. Thus all the means of union of the articulations had been completely severed, and the bones of the forearm were only held to the carpus by some bundles of fibres, which passed posteriorly from the triangular ligament to the internal side of the carpus.

Bones.—The radius did not present any trace of fracture; the body of the ulna was also unbroken, but its styloid process was torn from the rest of the bone, although still held by ligament and tendon, as above mentioned. In the new position which the bones of the forearm had accidentally assumed, relatively to the carpus, they concealed and lay in front of the whole first range of carpal bones, and had been arrested in their descent only by the true annular ligament, and the tendons of those flexor muscles which pass behind this ligament."*

Let us suppose now a transverse fracture of the radius, situated near to the wrist-joint, with the displacement backwards of the inferior fragment. This kind of accident will most simulate a luxation of the wrist, such as the foregoing case, in consequence of the size of the two eminences, the one placed anteriorly, the other posteriorly; but in fracture the anterior and posterior saliency, in general, are not very conspicuous; while in luxation the posterior formed by the carpus, and the anterior by the bones of the forearm, have each a thickness of more than half an inch.

It is very true that we have seen cases (see *fig.* 933., for example) of fractures through the junction of the lower epiphyses of the radius, with fracture also of the ulna, which even in this amount of saliency of the anterior and posterior prominency, much resembled the case of a dislocation; but the saliency posteriorly in the case of the dislocation is formed only by the rounded summit of the carpus, and the measurement from this point to the ultimate extremity of the middle finger gives only the normal length of the hand; whereas, if the deformity at the back of the forearm resulted from a fracture of the radius with displacement backwards of the lower fragment surmounting the carpus, a measurement taken from the summit of the dorsal prominence to the end of the middle finger would show an increase of at least half an inch over the normal length of the whole hand, because to the summit of the carpus in the case of fracture with displacement is superadded the amount of the depth of the lower fragment of the radius. By this test of measurement, therefore, we might settle our diagnosis between these two accidents which so much resemble each other.

The styloid process, too, of the radius can be felt still holding its normal relation to the carpus in cases of fracture, and to move with the hand when any motion is communicated to it; whereas, in the rare dislocation of the wrist-joint, which we are here considering, the lower extremity of the radius and ulna will be found placed in front of the carpus, and here, too, form an abrupt swelling, just above the superior margin of the annular ligament of the wrist.

Dislocation of the bones of the forearm backwards with displacement forwards of the carpus. — It is said that this dislocation, which is the reverse of the foregoing case of Voillemier, may occur as the result of accident.* Upon this head all we have to say is, that this dislocation of the bones of the forearm backwards at the wrist-joint, as the result of accident, must be exceedingly rare; but that, on the other hand, this is the very displacement of the bones which so usually exists in almost all cases of congenital dislocation of the wrist-joint (*figs.* 924. and 925.).

Luxations of the lower extremity of the ulna. — There are two species of this luxation of the lower extremity of the ulna. In one, the ulna escapes from the sigmoid cavity of the radius in passing *backwards*; in the other, it is by the anterior part of the articulation that the displacement occurs. Luxation of the inferior extremity of the ulna *backwards* is the more frequent of the two; that *forwards* must be rare, says Boyer, for I have seen but one

* Archives Générales de Médecine, Decemb. 1839, p. 401.

* See Nelaton, Elémens de Pathologie, vol. ii. p. 408.

example of it, and Dupuytren mentions that he has met with but two. Sir A. Cooper refers to only one case of dislocation of the lower extremity of the ulna. In this case the bone was thrown backwards.

Luxation of the lower extremity of the ulna at the wrist-joint, backwards. — Desault has published the history of a washerwoman who had a luxation of the inferior extremity of the ulna *backwards*, in consequence of the violent and sudden pronation in which the wrist had been forced into while she was in the act of wringing clothes.

In this luxation, *backwards*, the forearm and hand are in a state of forced pronation, and the two bones are strongly crossed, forming with each other a very acute angle of decussation; the inferior part of the forearm is much narrower than in the normal state; the forearm, the hand, and the fingers, are maintained in a state of moderate flexion, but fixed; the tendons of the flexor muscles of the finger are, as it were, matted together into a single fasciculus, displaced inwards, and form a sensible saliency upon the ulnar border of the radius.

What strikes one most, in looking at the back part of the wrist, is the very manifest projection on the dorsum of the region, formed by the lower extremity of the ulna, which rises so much above the level of the back of the hand.

Luxation forwards. — Desault, Boyer, and Dupuytren have each adverted to this dislocation, in which we observe an oblique crossing of the bones of the forearm; the fingers are semiflexed, and there is a remarkable narrowness of the inferior part of the limb. The forearm and hand are fixed into a state of supination, the saliency of the ulna is perceived in front, the tendons of the flexor muscles are pushed outwards towards the radius, and the inferior part of the ulna, instead of being parallel to that of the radius, as in the normal state, is oblique from above downwards, from within outwards, and from behind forwards.

Boyer gives the following remarkable example of this accident. In 1791, a woman of a strong constitution, and of a spare, though muscular frame, while in a state of intoxication, looking at two persons playing "domino" in a café, in Paris, foolishly ventured some advice to the players, who besought her not to interrupt them. She, however, thought proper to persist in giving her gratuitous advice, until at last one of the players, a strong and vigorous man, got up in a very angry mood, seized her violently by the right hand and endeavoured to push her out of the room. In this movement her hand and forearm were carried suddenly into a state of preternatural supination. Immediately the woman experienced the most acute pain, and cried out that her wrist was broken. The pain, the deformity, and the impossibility she experienced of executing the ordinary movements of the forearm, made her fear that she was most seriously injured. "I was called in," says Boyer, "instantly, and I found the patient complaining of most acute suffering, having the forearm flexed, the hand fixed in a forced state of supination. The least effort to communicate a movement of pronation caused the patient the most acute aggravation of her sufferings. The ulna formed a very sensible prominence anteriorly, and this bone, instead of being parallel to the radius, formed with it an acute angle, crossing its direction somewhat, and passing downwards, forwards, and outwards." All these symptoms taken together left no doubt on the mind of Boyer, but that the case he had to deal with was one of luxation *forwards* of the lower extremity of the ulna. It was not until after having tried thrice unsuccessfully that at length he succeeded in reducing the dislocation.

Luxations of the inferior extremity of the ulna forwards from the scaphoid cavity of the radius are, according to the opinion also of Dupuytren, excessively rare, at least, "in the course of my long practice," he says, "I have met with but two cases of this accident." One of these cases he gives us a detail of, as follows: — *Case.* M. Blot, an officer of the gendarmerie, æt. 32, of a sanguine temperament and athletic constitution; while on duty during the night, the horse upon which he was mounted took fright, reared up, and fell back with his rider. The latter was happy enough during the fall to disengage himself nearly from the animal, with the exception that his right arm was placed between the head of the horse and the ground, and thus received a violent shock. M. Blot, considering his forearm broken, applied to two surgeons, who, each in succession, recognised a dislocation of the ulna at the wrist, and each, also, failed in reducing the dislocation. M. Blot came to Paris, suffering much, and applied at the Hotel Dieu to Dupuytren, on 25th November. He then laboured under the following symptoms: — The forearm was much swollen; the hand was in a median position between pronation and supination; the inferior part of the forearm was deformed, rounded or rendered cylindrical near the wrist-joint by the diminution of its bilateral diameter — a remarkable saliency existed within and in front, formed by the lower extremity of the ulna thrown forwards towards the palmar aspect — behind, a remarkable depression replaced the accustomed prominency formed by the lower extremity of the ulna (la malléole interne); indeed, behind, a depression existed instead of the saliency ordinarily formed by the head of the ulna. If we followed with the fingers the ulna, from the elbow even to the hand, we perceived that this bone directed itself obliquely forwards and outwards in crossing and passing over the inferior part of the radius. The luxation of the radius *forwards* became then evident. There was no crepitation. The movements of pronation and supination were completely lost. Dupuytren having failed at the first attempt, he succeeded in reducing the luxation by inclining the hand forcibly to the radial side, and pushing with his two thumbs, united the displaced extremity of the ulna inwards and backwards. By this process the reduction was affected. The patient cried out at once, "I am well." All deformity had disappeared, and the motion of pronation and supination were restored. (Gazette Médical, Malgaigne.)

Such cases as these, says Dupuytren, ought to be recorded by every surgeon when he meets with them, in consequence of their rarity and importance.

Luxation of the bones of the carpus. — The bones of the carpus are united to each other so solidly, and their movements are so limited, that without experience, we should be disposed to pronounce luxation of any of these bones impossible. Nevertheless, the head of the os magnum may be dislocated from the cavity formed for it by the scaphoid and semilunar bones. The first range of the bones of the carpus is articulated with the bones of the second range in such a manner that slight gliding movements of flexion and extension of the hand are permitted, which augment a little the movements of flexion aud extension of the hand upon the forearm, and add somewhat, as Cruveilhier says, to the grace of the movements of this portion of the upper extremity. In flexion, the head of the os magnum, which is somewhat inclined backwards, raises up the thin capsule which surrounds its articulation, and if this movement be carried very far, the capsule and accessory fibres which support the bone posteriorly are broken, and the os magnum escapes from the cavity in which it is naturally placed ; the dislocation cannot be called complete, yet the os magnum passes somewhat the level of the posterior surface of the other bones of the carpus.

The accident is more common in women than in men, no doubt because the ligaments are weaker and the bones enjoy greater motion in the former, than in the latter. The luxation backwards of the os magnum, the only one which can occur, is always the result of a forced and violent flexion of the wrist, such, for example, as a fall on the back of the hand would produce. We recognise the luxation of the os magnum by the history of the accident, and by the deformity produced. We perceive a hard, circumscribed tumour, which has suddenly appeared on the back of the hand, in the situation which corresponds to the head of the bone. This tumour becomes more prominent when the hand is flexed, and diminishes when it is extended : we can make it disappear entirely by a slight compression. This luxation causes but little inconvenience ; but the head of the os magnum always remains more salient when the hand is flexed, and forms a tumour, more or less marked, according to the extent of the displacement.

We can easily reduce this luxation by extending the hand, or by exercising a slight pressure on the head of the os magnum ; but, although it is easy to make the bone resume its position in the cavity formed for it by the scaphoid and semi-lunar bones, it is very difficult to maintain it there, and the inconvenience and deformity resulting from the luxation are so trivial, that few persons will submit with patience to the means usually recommended.

Fractures of the lower extremity of the radius in the immediate vicinity of the wrist-joint. — We believe that the first important effort to direct attention to the peculiarities which the fracture of the lower extremity of the radius presents, was made by the late professor of surgery, of the College of Surgeons, in Dublin, Dr. A. Colles, in the year 1814.* Subsequently, we find Sir A. Cooper, in London, and Dupuytren, in Paris, each pointing out the importance, in a practical point of view, of our studying this accident, and distinguishing the case of fracture of the radius with displacement backwards of the carpus, from true dislocation backwards of the hand at the wrist-joint.

Velpeau followed these, concurring with them in the opinion that a transverse fracture of the lower extremity of the radius was a very common injury, and frequently mistaken for a dislocation. He seemed to be even more positive than his predecessors in maintaining the doctrine that no accidental luxation of the wrist-joint could occur without a fracture of some of the bony processes, or laceration of the integuments.

This fracture is rarely attributable to any direct cause; it appears, however, that Hublier communicated to the Academy of Medicine the case of a young girl, who having had the wrist caught between the pole of a carriage and a wall, had gotten a *transverse* fracture of the lower extremity of the radius. In this case there was combined with the above mentioned transverse fracture, another vertical one at right angles with it, dividing into two the lower fragment, constituting what in other articulations we have elsewhere in this book (vide KNEE, ELBOW) denominated a T fracture. This species of fracture by direct violence, corresponds much to the cases described by Dupuytren as "Fracture par écrasement." Fractures of the radius may be caused by falls on the back of the hand, but by far the most frequent sources of the fracture in question are falls on the palm.

Malgaigne asks, by what mechanism are these fractures of the lower extremity of the radius specially produced. In reply he adduces the following experiment by Nelaton : — The latter amputated the forearm of a dead body at the elbow, and cut off the olecronon at a level with the head of the radius. He then applied the palm of the hand of the subject on a solid plane, the forearm being at the same time directed vertically; he now with a mallet struck a heavy blow directly on the superior extremity of the two bones of

* *Vide* Edinb. Med. and Surgical Journal, vol. x. 1814.

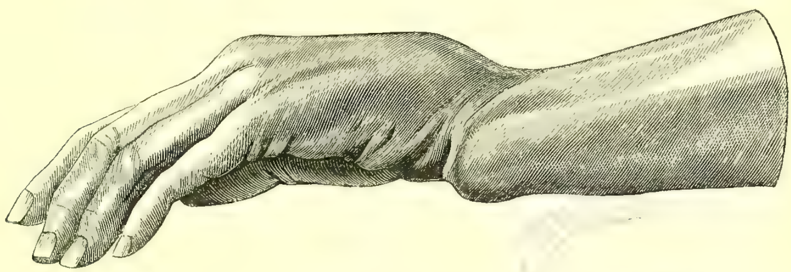
the forearm. The wrist broke and became immediately deformed. The dissection revealed a simple and transverse fracture of the carpal extremity of the radius, with a displacement backwards of the lower fragment, as with ordinary cases of fracture of the radius in the immediate vicinity of the wrist-joint, a species of injury, which in this city is known by the name of "Colles' fracture."

It would also appear to Malgaigne, Bouchet, and Voillemier, that this fracture may be the result of a sudden and violent flexion of the hand without the patient having had any fall. This fact was first established by Bouchet, who, in endeavouring to produce dislocation of the wrist on the dead body, only caused in his experiments fractures of the inferior extremity of the radius; sometimes with other disorders, and more particularly with a simultaneous fracture of the styloid process of the ulna.

Symptoms. — If Colles' fracture of the radius be produced by a fall, the patient will, sometimes, be able to say that at the moment of the accident he felt a sensation of something having given way near to the wrist-joint. The inferior extremity of the forearm and the hand swell; the fingers are semi-flexed, and the patient experiences the greatest difficulty in performing the ordinary movements of the hand, or forearm. He usually presents himself to us with the hand of the injured forearm resting on its ulnar margin, and supported by the other hand, and in a middle state between pronation and supination.

The posterior surface of the forearm usually represents a considerable deformity; for a depression is seen to exist about one inch above the line of the wrist-joint, whilst a considerable swelling occupies the wrist itself and metacarpus; indeed, the carpus and base of the metacarpus, appear to be thrown backwards so much, as at first view to excite a suspicion that the radius had been dislocated forwards, and the carpus and hand back-

Fig. 930.



"*Colles' Fracture.*"

wards (*fig.* 930.). On viewing the anterior surface of the limb we observe a considerable fulness, as if caused by the flexor tendons being thrown forwards; this fulness extends upwards, to about one-third of the length of the forearm, and terminates below at the upper edge of the annular ligament of the wrist.

The inferior fragment of the radius being salient posteriorly, while the superior is thrown forwards, the injured forearm, viewed side-ways, resembles, in the undulating direction of its long axis, the outline, according to Velpeau's idea, of a silver dinner-fork. Besides presenting this very striking deformity, in this fracture we find the hand occasionally thrown outwards, or towards the radial side, and then the carpal extremity of the ulna presents a strong saliency internally. The degree, however, in which this projection towards the inner edge of the wrist takes place, will be found to vary.

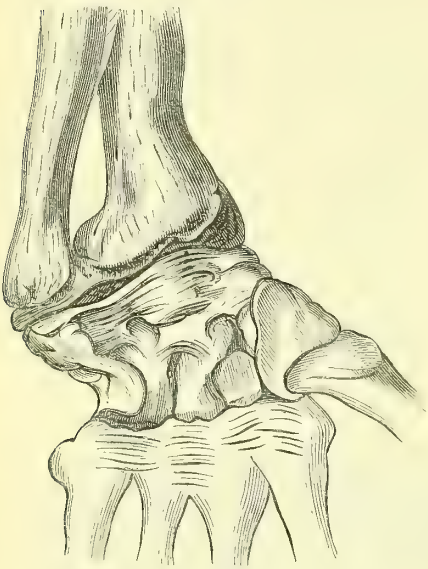
The patient is unwilling to attempt to pronate or supinate his hand, and if we endeavour to communicate such movements, much pain is produced. There is considerable pain felt by the patient when we press firmly with the point of the finger in the exact situation of the fracture.

The internal lateral ligament of the wrist-joint is generally put upon the stretch, and the patient usually complains of much distress here; but this pain, which some patients feel about the lower extremity of the ulna, does not always arise simply from a sprain coincident with the fracture or from a rupture of the internal lateral ligament of the articulation of the carpus with the forearm, but we believe sometimes is owing to a fracture of the root of the styloid process of the ulna.

It is in this last case more particularly that the hand "par un mouvement de totalité," is carried *outwards*, and that the ulna seems *very* salient, internally (*fig.* 931.).

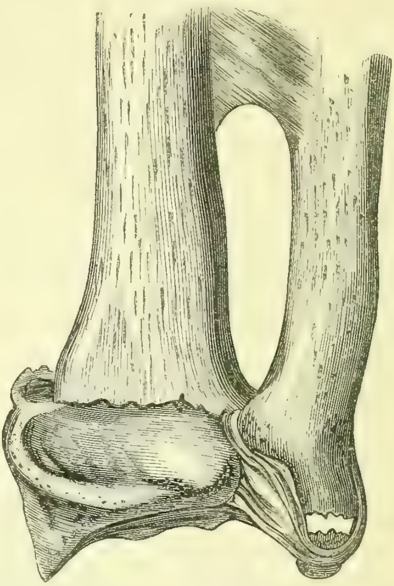
A narrowing of the region of the wrist, in the transverse direction, has been much adverted to by Dupuytren, as a symptom of the fracture we are now considering, but we believe this narrowing is, in general, more apparent than real. We rather concur with Velpeau, who says, "Many observations have induced me to believe that Dupuytren, and others, have been deceived as to the supposed narrowing of the wrist." He adds, an interosseous space, in reality, does not exist near to the wrist joint; indeed, there is scarcely any open interval to be seen between the lower extremity of the radius and ulna for the space of one inch above the line of the radio-carpal articulation. Now, fractures ordinarily take place at a point which is below the level of this line, and any displacement, the result of fracture, cannot readily affect the breadth of the interosseous space, placed above the line of the fracture.

Fig. 931.



Cooper, who asserts that in this fracture a very powerful extension is required to bring the broken ends of the radius into apposition.

Fig. 932.



After Malgaigne.

It is only in cases where the fracture is situated so high as an inch and a half, or more, above the joint, that any abnormal approximation of the bones towards each other, and ultimate obliteration of the interosseous interval is to be dreaded.

Although therefore, as a result of Colles' fracture, we observe the forearm assume, near the wrist-joint, a cylindroidal form, there may be no real narrowing whatever, but the appearance of it may be attributed rather to an increase, in the antero-posterior diameter of the region of the wrist, than to any real diminution which occurs transversely.

Malgaigne has, however, adduced an example to explain how, in certain rare cases, a diminution of the transverse diameter of the forearm may occasionally take place, and by the action of the pronator quadratus not on the inferior, but on the upper fragment of the radius. (*fig.* 932.)

It is said by some, that crepitation, caused by the movements of the fragments of the broken radius on each other, can always be elicited, and that this sign is diagnostic of fracture; moreover, that the deformity is easy to reduce by extension, but liable to return when the extending force is removed. Such observations, no doubt, may sometimes be made with truth. For our own parts, we do not think that crepitation can, except in a very few cases, be elicited in Colles' fracture of the radius. We have found it to be an injury attended with a deformity which can, it is true, be removed by extension, but our experience corresponds with that of Sir A.

Diagnosis.— In many cases, a fracture of the radius in the immediate vicinity of the wrist-joint is attended with so much deformity, and accompanied with such characteristic appearances, that the observation of Pouteau appears well founded, that it can be recognised at the first "coup d'œil;" but on the other hand, there are some cases in which very little external evidence of any fracture can, without careful examination, be detected. The undulating curve, which has been compared to that represented by a silver fork, cannot exist without fracture, and the elevation from the level of the back part of the radius of the common extensor tendons is another feature, which we believe with Velpeau to be peculiar to fracture; we know that in the normal state the tendons of the extensor carpi radialis longior and brevior remain applied as longitudinal bands, lying flat on the posterior surface of the radius, and no interval whatever exists between these two bands and the back part of this bone near to the wrist. Now, when there is a fracture of the radius here, this bone is rendered somewhat concave on its posterior surface, and these tendons must, of necessity, abandon the bony surface, and be raised up several lines from it, so as to represent a cord, more or less tense, but easy to depress. If, for example, the hand of the patient being a little flexed, the surgeon in examining these cases, places his finger or thumb three or four lines above the level of the wrist-joint, on the posterior surface, and near to the external border of the radius, he will, if fracture exist, recognise beneath the skin the tense cord, and perceive that it can be depressed even to the posterior surface of the radius, from which it had been manifestly elevated. This last is a test upon which Velpeau specially relies.

Upon the subject of Diagnosis of this fracture of the carpal end of the radius, Dr. Colles remarks, —" the facility with which the surgeon can move the ulna backwards and forwards, does not furnish him with any useful help in his diagnosis as to the true notion of the injury. Moreover, when he moves his fingers along the anterior surface of the radius, he finds it more full and prominent than is natural ; a similar examination of the posterior surface of this bone, induces him to think that a depression exists about an inch and one half above its carpal extremity. He now may expect to find satisfactory proofs of a fracture of the radius at this spot. For this purpose he attempts to move the broken pieces of the bone in opposite directions, but, the patient is by this examination subjected to considerable pain, yet neither crepitus, nor a yielding of the bone at the seat of fracture, nor any other positive evidence of the existence of such an injury is thereby obtained. At last," adds Dr. Colles, " after many unsuccessful trials, I hit upon the following simple method of examination, by which I was enabled to ascertain that the symptoms above enumerated actually arose from a fracture of the lower extremity of the radius: — let the surgeon apply the fingers of one hand to the seat of the suspected fracture, and locking the other hand in that of the patient, make a moderate extension, until he observes the limb restored to its natural form. As soon as this is affected, let him move the patient's hand backward and forward, and he will, at every such attempt, be sensible to a yielding of the fractured end of the bone, and this to such a degree as to remove all doubt from his mind."

I have already stated that sometimes the fracture may exist without being accompanied by any appreciable displacement of the bones. The patient complains of a severe pain in the region of the wrist, when pressure is made on the broken part, and also when the forearm is moved. These are the only symptoms which exist, (if we except a slight swelling, particularly observable on the anterior surface of the wrist,) so that one would be tempted to believe that there was only a simple sprain existing. If, however, we make pressure on the line of the articulation, we do not cause the patient any pain, which we should do, if the symptoms arose from a sprain, while if the same degree of pressure be made a few lines *above* the joint, the pain is very severely felt. Now, if we place a thumb on the radius behind, in the presumed seat of fracture, and make the effort to bend the wrist at this part, so as it were to make the forearm here form an angle on itself, salient anteriorly ; if the angle be thus formed, we hereby obtain a pathognomonic sign of the fracture ; and a comparison of the two wrists submitted equally to this experiment, puts the matter beyond all doubt.*

Fractures of the lower extremity of the radius are generally looked upon as serious injuries. If this fracture has been mistaken for a sprain, or luxation, or abandoned to nature, according to Dupuytren, very serious changes ensue. " The forearm, in the region of the wrist, instead of presenting a surface flattened anteriorly, will assume a cylindroidal form. The movement of pronation and supination will be lost, an œdematous swelling of the soft parts will continue ; the articulation remains immovable for a considerable time, and, if a rupture of the lateral ligament of the inferior radio-cubital articulation, or fracture of the styloid process of the ulna be superadded to the fracture of the lower extremity of the radius, we may see continue for life the abnormal mobility of the two bones on each other." Mr. Diday, of Paris, has gone further, and asserted that these consequences of fracture of the radius, above alluded to, are often observed, in spite of all kinds of treatment, and of bandages, which modern surgery has suggested.

In making an estimate, as to the amount of evil resulting from the fracture of the lower extremity of the radius and its usual consequences, we find authors differ. Velpeau would seem to attribute many of the evils alluded to by Dupuytren rather to improper bandages, and the manner of treating the injury, than to anything in the nature of the accident itself.

Although written so many years ago, the opinion of Dr. Colles, as to the prognosis in these cases, seems to us nearer the truth than any of the above mentioned conflicting observations of the authors alluded to.

Dr. Colles remarks, " that should the case be treated as a case of sprain, and the fracture left unreduced, the practitioner will find, after a lapse of time, sufficient for removing similar swellings, that the deformity is undiminished. By such mistakes the patient is doomed to endure for many months considerable stiffness, and lameness of the limb, accompanied by severe pains, in attempting to bend the hand and fingers ; one consolation only remains, the limb will, at some future period, again enjoy perfect freedom in all its motions, and be completely exempt from pain, the deformity will, however, remain undiminished through life."

Upon the whole, then, we may safely say, that when the fracture we have been describing has nothing unusual in it, and is only accompanied with the ordinary displacement backwards of the inferior fragment, that the case generally proceeds favourably.

If the true nature of the accident has been early recognised, and proper and sufficient extension made of the forearm, the peculiar characteristic curve disappears, not to return; the fingers are found to be much more free in their movements, and can be more fully

* See Colles and Malgaigne.

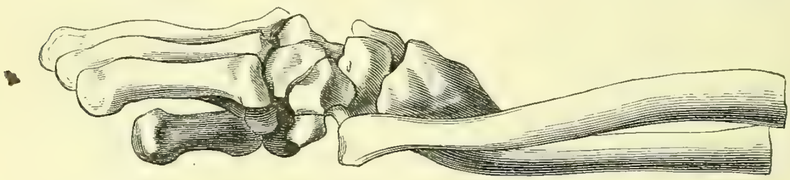
extended than before; the pain disappears, and in about a month after the fracture has occured, if judicious treatment be adopted, the union of the fragments is so perfect, that the passive motion to restore the joints to their primitive suppleness may be commenced.

Notwithstanding, therefore, the opinions of Dupuytren, Diday, &c., &c., we think that, as a general rule, in the case of Colles' fracture the prognosis is favourable.

It may be otherwise, if the styloid process of the radius be elevated much above its natural level, if the hand has quitted, partially, the lower end of the ulna, so as to be carried "par un mouvement de totalité" outwards, and if the case has not been early recognised.

Anatomical characters of the Fracture. — On dissection, it will be found that the hard swelling which occupies the back part of the hand and wrist, is caused by the displacement backwards of the lower fragment of the radius, and the carpus carried with it in this direction. As a consequence of the altered direction of the radius, we find that the aspect of the carpal articular surface of this bone is altered, and instead of being directed, as it normally is *, downwards and somewhat forwards, it is now directed downwards and backwards (*fig.* 933.); the carpus and metacarpus retaining

Fig. 933.



their connexion with the broken radius *must* always thus follow this bone in its derangements, and cause the characteristic dorsal convexity above alluded to. The change of direction of the articular surface of the radius is well shown by measuring the length of the broken radius in these cases, both on the palmar and dorsal aspect of this bone longitudinally, when it will be found that in Colles' fracture, the posterior measurement is several lines less than the anterior, which is exactly the reverse of what this measurement normally should be.

We dwell upon this abnormal obliquity of the lower articular surface of the radius, for in the treatment of this injury it should be our principal aim to remedy this obliquity, and, as it were, reverse it, and thus make the aspect of the articular surface look as it should normally do, downwards and forwards.

The change of direction of the articular surface is caused by the extensor muscles of the carpus, and of the thumb, and by their tendons, which pass along the posterior surface of the radius in sheaths, firmly connected with the inferior extremity of this bone, to which deviation in the direction of the lower fragment the action of the supinator longus muscle and its tendons may also somewhat contribute.

Professor Smith, who has investigated laboriously the anatomy of the bones in this injury, says he has discovered nothing to invalidate the truth of the general proposition first maintained by Voillemier, namely, that when the radius is broken within an inch of its lower extremity, the direction of the fracture is usually transverse; but we find that he differs entirely from this last-named author upon the doctrine of the fracture of the radius in question, being one by impaction. It is very true, he says, that in every instance of the ordinary fracture of the carpal extremity of the radius, which he had an opportunity of examining anatomically long after the occurrence of the injury, he found upon making a section of the bone, from before backwards, a line of compact tissue continuous with the posterior wall of the shaft, extending to a greater or less distance into the reticular texture of the lower fragment; but he cannot agree with Voillemier, that this appearance affords evidence of impaction of the upper fragment into the lower. In the only recent specimen Mr. Smith had an opportunity of examining, the lower fragment was displaced backwards, the superior projecting one-eighth of an inch in front of it. There was no impaction whatever in this recent specimen, of either fragment into the other, nor any line of compact structure penetrating the reticular tissue of the lower fragment.

If the doctrine of impaction were true, the shortening of the radius in cases of fracture of its lower extremity, should be much greater than it ever is, for there is a second cause of shortening in operation, *i. e.* the alteration in the direction of the articulating surface, in consequence of which the posterior surface of the radius (naturally longer than the anterior) becomes the shorter of the two. Now, if to the degree of shortening produced by this cause we add that arising from impaction, we should have an amount of shortening much greater than ever occurs in the case of Colles' fracture; indeed, after adducing other arguments against the theory of Voillemier, as to this being a case of fracture by "*penetration*," Mr. Smith further remarks, that as long as the ulna remains unbroken and the ligamentous connexion between the two bones uninjured, it is scarcely possible for either fragment to

* We always take it as understood that the patient is in the erect posture.

penetrate the other, even to the extent of half an inch.

We agree with Velpeau, Smith, &c., in thinking that in this injury, Colles' fracture, there is scarcely any diminution of the transverse diameter of the forearm. The cylindroidal form which the arm acquires being owing partly to an effusion among the flexor tendons, but principally to the increase of the antero-posterior diameter of the forearm at the seat of the fracture, consequent on the backward displacement of the lower fragment.

I have never seen the case, spoken of by many, of *transverse fracture of the radius, with displacement forwards of the hand and lower fragment*, which accident is said to be produced by a fall on the back of the hand.

Fracture of the lower extremity of the Ulna. — A fracture of the lower extremity of the ulna is rather a rare accident, because, perhaps, of the great elasticity of this long and slender bone, and the mobility of its lower end, by which it, as it were, eludes the force which might otherwise cause its fracture. Indeed the ulna, it will be recollected, is not directly connected with the hand as the radius, the "manubrium manus," is: and hence, when a patient falls on the palm of the hand, the whole force of the weight and impulse are sustained by the radius; but if this last bone gives way, and a transverse fracture occurs, with displacement backwards of the hand and lower fragment, then, as a secondary consequence, a fracture of the ulna, near the wrist-joint, may follow. In the vast majority of cases, however, of fracture of the radius close to the wrist, which occur, for example, in Colles' fracture, the ulna remains unbroken.

Fracture of the lower extremity of the ulna may also be the effect of direct violence.

When the ulna is broken alone, without being accompanied by any simultaneous fracture of the radius, it may be recognised by the pain felt by the patient when direct pressure is made on the broken part of the ulna, and by the difficulty he experiences whenever he attempts to pronate or supinate the forearm. When the surgeon takes hold of the lower fragment of the ulna, and moves it backwards and forwards, crepitation can be felt.

Fracture of the lower extremity of the ulna is an accident which requires much attention from the surgeon, as sometimes, if the separated fragment be small, as, for example, consisting merely of the styloid process of the ulna, no union may occur, and permanent weakness of the wrist-joint may follow.

Disjunction of the lower Epiphysis of the Radius. — This must be considered rather a rare accident; it is, however, occasionally to be met with; and the history of the art of surgery furnishes us with well-marked examples of it, as the three following cases sufficiently prove: —

CASE 1. — "I have," says Cloquet, "observed one case of the disjunction of the lower epiphysis of the radius, in a young lad twelve years of age, who fell from a considerable height from a tree to the ground. Besides the injury done to the radius, he received, at the time of the fall, a wound of the head which in three days proved fatal to him."

Dissection. — The epiphysis of the right radius was entirely separated, and a great quantity of blood was effused in the deeper palmar region, behind the tendons of the deep flexor muscles of the fingers (Diction. de Médecine, 1824).

CASE 2. — Rognetta has adduced a similar case of a lad at fifteen years (Gazette Médicale, 1834.).

CASE 3. — In December 15th, 1838, the writer laid a case before the Pathological Society of Dublin, which was a true specimen of a disjunction of the lower epiphysis of the radius.

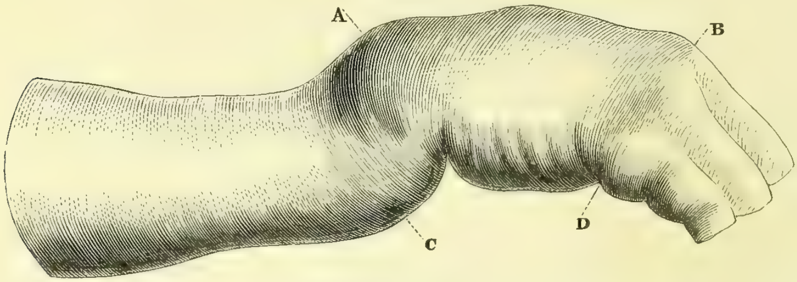
The patient, having been above eighteen years of age, had attained to a more mature time of life than any other example of this special injury affecting the wrist hitherto recorded; a representation of the external appearance which the lower part of the forearm and carpus presented in this case have been preserved by a plaster cast; and after the death of the patient, the actual condition of the parts having been ascertained anatomically, these circumstances, in the writer's opinion, make this case valuable.

A. B., æt. eighteen, a mason, fell from a scaffold which was attached to the front of a lofty house at its third story. By the fall he received a severe injury of the head, which rendered him immediately insensible, and in this condition was admitted into the Richmond Hospital. Besides the injury of the head, we noticed in this case a remarkable lesion; the right wrist had suffered a derangement, accompanied with a deformity that at first sight we might suppose would be produced by a dislocation of the carpus and hand backwards on the dorsum of the forearm (*fig.* 934.). The plane of the hand and carpus were placed fully three quarters of an inch behind the plane of the rest of the forearm; and from the external appearances there seemed no doubt but that there was an abrupt transverse solution of continuity of the forearm, close to the wrist-joint, which equally affected both radius and ulna.

On viewing the limb laterally, the peculiar curve which Velpeau compared to the back of a silver dinner fork, was exaggerated beyond what we noticed in the ordinary fracture of the radius in this situation; and the tendons of the extensors, particularly those of the extensor carpi, were thrown remarkably into relief. The anterior, or palmar surface of the forearm presented a longer and more uniform curve than the posterior; the depth of the antero-posterior diameter of the wrist in the seat of injury was much increased: so that this and the bilateral measurement seemed equal.

Thus the accident presented many of the appearances of the dislocation, backwards, of the hand and carpus; but the longitudinal measurement, taken from the highest part of the dorsal prominence to the root of the index finger (*from A to B fig.* 934.), on the injured side, gave an excess of length of half an inch over that of the opposite hand. This excess of length was manifestly caused by the presence of the disjoined epiphysis, which

Fig. 934.



Disjunction of the Epiphysis of the Radius, with displacement backwards of the Hand and Carpus. — Author's Collection.

had been superadded to the summit of the carpus, and was carried back with it, the wrist-joint itself remaining perfect.

This simple test of the comparative measurement proved the case was not one of mere dislocation of the hand; but we may also add, that, although there was considerable swelling and projection forwards of the palmar surface of the region of the wrist, there were not those hard protuberances to be felt in front of the carpus which the extremity of the radius and ulna, with their styloid processes, should have presented had the dislocation above alluded to occurred.

The man died, in a few hours after admission, from the injuries he received, particularly of the head.

It had not been deemed advisable to reduce the fracture, as the man seemed to be in a dying state.

Dissection. — With the assistance of my friend, Dr. Power (now Professor of Anatomy of the Royal College of Surgeons, Dublin), I removed the greater part of the forearm, that we might the more carefully examine the true nature of the lesion, the external appearances of which we have above described.

On making, then, the anatomical examination of the parts composing the region of the wrist in this case the radius was found to have suffered a transverse interruption of continuity in the line of junction of its inferior epiphysis, and the lower fragment was displaced directly backwards, so far as nearly to have passed the extremity of the upper fragment (*fig.* 935.). The lower extremity of the ulna was broken a short distance above the line of junction with its epiphysis. This fracture was oblique. The extremities of the two fragments of the ulna formed with each other an angle salient in front. The ligaments and the radio-carpal articulation also remained uninjured, and the carpus (of course) accompanied the lower fragment of the radius in its displacement backwards.

CASE 4. — A boy, æt. eleven, was admitted into the Richmond Hospital on the 2nd of September, 1840, under the care of Dr. Macdonnell. Upon the Sunday previous to his admission he had been thrown from a horse with great violence. The lower extremity of the left radius was broken, and he sustained a

Fig. 935.

Disjunction of the Lower Epiphysis of the Radius, with fracture of the Ulna, and displacement backwards of the Carpus and Hand. — Museum of the Richmond Hospital.

concussion of the brain, under the influence of which he remained insensible for three quarters of an hour. The accident occurred at some distance from town. Before an hour elapsed the boy was visited by a surgeon, who, it is said, forcibly extended the limb, and then applied a narrow roller tightly round the wrist. On the following day (Monday) the patient complained of intense pain in the limb; the hand became cold and discoloured; the roller was not removed nor relaxed. On Tuesday, dark coloured vesicles formed; constitutional symptoms of the gangrene showed themselves; the pulse 159, feeble; countenance anxious. The gangrene increased for two days more, and reached within two inches of the elbow-joint. On the sixth day a line of separation showed itself; and on the twenty-fourth day the bones were sawn through, and the wound soon healed.

Dissection of amputated Forearm. — The radius was found to have been completely broken through in the line of junction with its lower epiphysis. The ulna was entire. The preparation of the disjoined epiphysis and gangrened hand is preserved in the Museum of the Richmond Hospital.

The causes which have been known to produce a disjunction of the epiphysis are said to be similar to those which produce a transverse fracture of the bone close to the wrist-joint: but why in one case we should have a fracture, and in another a disjunction of the epiphysis, we cannot say. All my own observation has, as yet, taught me relative to this subject from the cases I have seen and inquired into, has been that the cause producing the disjunction in question has always been a violent one.

When a patient has suffered a disjunction of the lower epiphysis of the radius, there is, in general, much deformity observable in the region of the wrist. The hand, carpus, and lower fragment are carried backwards, and form together a plane which is from half an inch to three quarters of an inch behind the plane of the back part of the rest of the fore-arm; the transverse line of elevation of the lower fragment above the level of the dorsum of the upper fragment of the radius is very abrupt and obvious: and the first impression on the mind is, that a dislocation backwards of the carpus and hand is the accident which has occurred. This abrupt transverse ridge and depression are crossed vertically by the extensor tendons of the carpus; and pressure with the fingers discovers these longitudinal tendinous bands to be on the stretch, having been forcibly elevated from the back part of the radius as they pass to their grooves formed in the lower fragment.

The palmar surface of the forearm is unusually convex from above downwards, and does not present a salient angle in front, such as we might expect from the abrupt depression we noticed on the dorsum of the wrist and forearm. This convexity of the forearm in front, however, abruptly terminates in a transverse narrow sulcus which marks the situation of the upper margin of the anterior annular ligament. The radial margin of the forearm is concave, and the ulnar margin presents a corresponding convexity. The patient complains much of pain, and has the same inability to move the forearm and hand as in cases of fracture.

By the above-mentioned signs we become informed that a solution of continuity in or near to the transverse line of junction of the lower epiphysis of the radius exists: but without having had any opportunity of instituting an anatomical examination, we believe it would be difficult for any one to affirm whether the case were one of fracture, or disjunction of the epiphysis. Some writers seem to think that the case of disjunction of the epiphysis may be recognised by the circumstance, that, although there is an evident solution of continuity in the line of the radius, the crepitus of an ordinary fracture cannot be produced. To which we reply, that the absence of crepitation is not by any means unusual in cases of fracture of the radius in the region of the wrist; and, therefore, from this observation no useful inference can be deduced to aid our diagnosis.

In the examples of disjunction we have seen, we have always noticed a fixed condition, as it were, from the interlocking with each other of the portions of the disjoined radius; so that it seemed quite vain to seek for crepitus; — indeed we found it invariably demanded a considerable force in these cases to restore the limb to its original form.

We believe it is impossible to make a *differential* diagnosis entirely to be relied on in these cases; but we may, we think, conjecture that the disjunction in question exists rather than a fracture, when the age of the patient is under eighteen or nineteen years, and the situation of the solution of continuity is in the exact transverse line of the junction of the epiphysis to the shaft of the bone. If, however, the diagnosis be difficult, we have *practically* little to regret this circumstance, because the prognosis and the treatment will be the same in both cases.

SECTION III. DISEASE. — In describing the alterations, the result of disease as it affects the other articulations, the abnormal anatomy of which we have already adverted to in this work, we have classed these morbid changes into those which are the consequence,

1st. Of Acute Arthritis.

2nd. Of Strumous Arthritis; that is to say, "a scrofulous disease of the joints, having its origin in the cancellous structure of the bones."

3rd. Of Chronic Rheumatic Arthritis.

Here we may adopt a similar arrangement, but shall find it necessary to add, —

4thly. A few observations on Synovial Tumours of the Region of the Wrist.

Acute Arthritis of the *radio-carpal*, and of the *inter-carpal* articulations, may be the consequence of a contusion or a wound, or it may originate in some internal cause, such as an acute rheumatic, or a diffuse inflammation.

Acute arthritis of *any* or *all* the joints which enter into the composition of the region of the wrist may be the consequence of a sprain or wound, or the inflammatory action may have been communicated to these joints by having extended along an injured tendon of the finger, or the inflammation, suddenly showing itself in the joints, may have originated in some unknown internal causes, such as those which preside over the development of an attack of an acute rheumatic arthritis, or of diffuse inflammation.

Whatever may have been the specific nature of the acute inflammation, there is soon noticed, besides the pain felt through the carpal region and the heat, that there is considerable swelling. This last is more particularly observed on the dorsum of the wrist and carpus than elsewhere. An effusion, whether of serum or pus, very soon takes place into the interior of the synovial sac, which will always have a tendency to distend this sac in all directions; but there can appear but little swelling at the anterior part of the articulation, because here a large fasciculus of flexor tendons of the fingers passes, and supports the synovial membrane. On the lateral aspect of the wrist-joint, the tumefaction, although sensible, is still limited by the resistance which the lateral ligaments oppose to the distension of the capsule. Behind, on the contrary, where the synovial membrane is unsupported and but superficially covered, the swelling, the result of the inflammation, soon becomes much more manifest, and fluctuation evident.

We are not aware of any case recorded in which complete dislocation of the hand, on the back part of the forearm or of this last forwards, had occurred as the result of acute inflammation. The only luxation, the result of acute arthritis in the region of the wrist, which has been noticed hitherto, has been that of the ulna backwards.

This luxation is not an uncommon result of an attack of acute arthritis of the wrist, by which the ligament which connects the ulna to the cuneiform bone becomes softened and lengthened, and permits of the ulna being dislocated partially or completely backwards. Bonnet has commented on the frequency of this backward displacement of the ulna, and looks upon it as the smultaneous effect of the facility with which the ligamentous ties of this bone become softened and elongated, and of the faulty position in which the hand is kept by the patient, who remains usually in bed during these acute attacks, and preserves the forearm and hand in a state of complete pronation,—a position which favours the displacement of the ulna backwards.

We have stated that acute arthritis of the wrist and carpal joints may be the result of inflammatory action, propagated from a wounded tendon of one of the fingers. The following is one of a few of those cases which had been admitted into the Richmond Hospital within a short period.

Case. — John Murphy, a labourer, æt. thirty-eight, while engaged in a fight with another labourer, received from him a bite in the little finger. The inflammation which followed involved the tendons and their sheaths, and spreading up the forearm, implicated in its passage the carpal and meta-carpal joints as well as the wrist and radio-ulnar articulation, all of which became ultimately disorganised. The amputation of the forearm, below the elbow-joint, became necessary. On making an anatomical examination it was found that there was complete disorganisation of the wrist-joint. All the bones of the carpus were loose and bathed in purulent matter.

Chronic Strumous Arthritis of the Wrist, or White Swelling. — This is a disease which is generally considered to have its origin in the cancellous structure of the bones. It is familiarly designated by many English writers by the well-known but somewhat equivocal name of "*white swelling*."

When we take into consideration that the bones and the joints which compose the region of the wrist are very superficially placed, and that they are frequently subjected to sprains and concussions from falls on the palm of the hand, we need not be surprised to find that these numerous injuries become so many determining causes, giving rise to a chronic inflammation of the bones and articular textures of the wrist, which frequently assumes the strumous character.

As to the symptoms of this disease, we have to observe that the patient complains of pain, sometimes in one point of the wrist, sometimes in another, which is increased on the slightest motion. Soon a swelling appears on the dorsum of the carpus, and the hand, from day to day, becomes more flexed on the forearm. After a time the region of the wrist assumes a globular form. The forearm, when compared with that of the opposite side, has an emaciated and wasted appearance. The patient usually has the hand supported on its palm, in the prone position, on some flat surface; the whole hand has a most helpless aspect; the fingers are swollen at their bases, and seem elongated and tapering towards their extremities: they are straight and motionless, and it is always with difficulty and pain that the patient moves them,— a circumstance we can easily account for, by recollecting that the inflammatory irritation which affects the wrist-joint is readily propagated to the tendons of the fingers which pass so immediately in front of it.

The synovial membrane in these cases is early distended by an increased secretion into the interior of the sac, and a fluctuating swelling may be occasionally perceived posteriorly, as in the case of acute arthritis; but in the case of white swelling, instead of true fluctuation, there is in general nothing but a deceptive feeling of it, from the infiltration of the tissues in the region of the wrist, by a glairy gelatiniform structure, similar to that which constitutes the chief bulk of white swellings in general.

During the second period of the disease, the degree of flexion of the hand and of the wrist-joint becomes increased, and the lower extremity of the bones of the forearm, particularly of the ulna, becomes very salient posteriorly. As the disease goes on, the bones of the carpus become more deeply carious; chronic symptomatic abscesses form, and their contents make their way to the surface, which is frequently studded over, in advanced cases, with the fistulous orifices of canals, which conduct purulent matter from the centres of some of the carious bones, and from the interstices between them. At this period of the disease we can, by holding the lower part of the forearm with one hand, and grasping the metacarpus with the other, move these parts laterally in opposite directions, clearly ascertaining that all the bones are loose and carious, and in an irrecoverable state of disorganisation. The constitution of the patient invariably sympathises deeply with this state of things; and the wasting effects of hectic fever are found usually coinciding with the disease of the wrist and carpus; and, if amputation be not performed, the life of the patient may be sacrificed. This operation, however, almost invariably succeeds in arresting altogether the hectical symptoms, and the patient is restored to health.

The scrofulous disease of the cancellous structure of the bones of the carpus, and of the carpal extremity of the radius, does not always proceed thus unfavourably. Occasionally, instead of suppuration, a resolution of the inflammatory action may ensue, or anchylosis, with partial displacement backwards of the bones of the forearm at the wrist-joint, may be established. This last, however, may be looked upon rather as an arrest of the morbid action than as a cure, because the patient is not only deprived of the use of the wrist, and sometimes of the medio-carpal joints, but also of the use of the fingers; inflammatory action in these cases having been communicated to the flexor tendons and their sheaths, rigidity of the ligaments, or even anchylosis of the joints of the fingers, too generally follows as a natural consequence.

It may here be asked, whether, in the progress of this disease, the wrist-joint is liable to those spontaneous displacements of the bones which other articulations affected with *white swelling* seem to be. To which we reply, If we except the partial displacement backwards of the ulna, previously mentioned, these displacements must be considered as rare. Bonnet of Lyons, who has had much experience, says he has not himself met with any case of spontaneous luxation of the hand, whether backwards or forwards, the result of disease; nor has he read of any such recorded. Nelaton relates, however, that Richet showed him a preparation found in the dead-room, in which it was observed that the bones of the carpus had lost their usual relation to the radius, the inferior extremity of which was carried into the palm of the hand, while the bones of the carpus were carried backwards on the dorsal surface of the forearm. Numerous fistulous orifices were seen, which evidently had, up to the period of the patient's death, furnished a purulent discharge, so that the disease had not been completely cured, although it was manifest that the ligaments had resumed their firmness and solidity, and that the luxation had taken place a long time previous to death.

Here, then, is a reply in the affirmative to the quære, whether spontaneous dislocation of the wrist-joint occur; and an unquestionable example of dislocation of the bones of the forearm forwards adduced, on the respectable authorities of Nelaton and Richet. To this observation we may add the following, showing that complete dislocation backwards of both the bones of the forearm may occur at the wrist (see *fig.* 936.); and here the testimony as to this fact rests also on the production of a specimen found in the dissecting room *; its history is unknown. By examin-

Fig. 936.

ing this preparation, in which the dislocation backwards of both the bones of the forearm had evidently taken place, we can observe much overlapping of these bones on the dorsum of the carpus, so that the styloid process of the dislocated radius quite overhangs the trapezium, even so far as the root of the meta-carpal bone of the thumb, and the ulna lies in contact with the back of the cuneiform bone, so that the articular extremity of the radius has passed down for more than an inch below its ordinary situation; the anterior surface of the bones of the forearm, when they lie on the dorsum of the carpal bones, are solidly united to them. (See *fig.* 936.)

Anatomical Characters of Chronic Strumous

* This specimen formerly belonged to the Museum in Park Street, Dublin, where I saw it. It now is to be found, I presume, in the Museum of the Queen's College, Belfast.

Arthritis, or White Swelling, of the Wrist. — When we remove the integuments from the wrist, in one of those advanced cases of chronic strumous disease of the radio-carpal and inter-carpal articulations, we encounter the usual appearance of a gelatiniform effusion, of a yellowish-green colour; we observe the tendons and nerves somewhat swelled, as if infiltrated; the ligaments all softened; purulent matter occupying the interstices of the articular surfaces; the bones easily yielding to pressure, hollow and carious in the centre of their cancillated tissue; and leading from these carious bones, are seen fistulous canals opening extensively by numerous orifices on the cutaneous surface of the wrist.

In the Museum of the College of Surgeons of Dublin we find a preparation, which is truly designated as an *instructive one*, showing the effects of scrofulous disease on the bones and other structures of the wrist. To save the patient's life, it became necessary to perform an amputation of the forearm. The hand has been preserved in spirits, and the back of the carpus has been laid open to view. The wrist is semi-flexed; the palm and fingers are swollen, and the front of the joint is studded with fistulous orifices. One solitary fistulous orifice appears in the centre of the palm. The bones of the carpus, deprived of their synovial membranes and ligaments, are loose and disjointed; and to use the words of the donor, the late Professor Todd, " they felt during life like a bag of marbles."

There is also another preparation, styled " scrofulous disease of the carpus, meta-carpus, and extremity of the radius," presented by Professor Porter. The bones are remarkably *soft*, *light*, and porous. The natural shape of each is considerably altered, by loss of substance in some parts, and deposits of new osseous matter in others: the latter, wherever it exists, has a peculiar spiculated appearance; some of the bones are increased in size, others diminished; the cartilages have, for the most part, disappeared; the synovial membrane of the smaller joints had been completely destroyed; that of the radio-carpal articulation was hypertrophied, soft, and pulpy. The ligaments were not recognizable, and the bones lay almost loose in a quantity of purulent matter, with which a fistulous orifice, in the front of the joint, communicated. The skin, the cellular tissue, and the sheaths of the tendons were infiltrated with a thin gelatinous fluid; the *median* and *ulnar* nerves were remarkably enlarged.

The scrofulous disease, commencing in the centre of the cancellous structure of the bones of the carpus and carpal extremity of the radius, does not always proceed thus unfavourably. Anchylosis, with partial displacement of the forearm at the wrist-joint, may, as already stated, be established, as the result of the morbid action we are here treating of.

In the Museum of Anatomy in Leyden there is a preparation of the bones of the wrist, in which the carpal extremity of the radius and ulna are much enlarged and remarkably scabrous on their surface; the radius and ulna are anchylosed firmly with each other near to the carpus; the os lunare was united to both radius and ulna; the os scaphoides, cuneiform and magnum, had totally disappeared; the trapezium was also firmly united to the meta-carpal bone of the thumb and with that of the index finger.

In the above-mentioned Museum at Leyden there is also another preparation, exhibiting anchylosis of the bones of the forearm, and of the carpus, at the wrist-joint, after the disease, which had arisen, we are told, from a scrofulous cause, had happily been cured.

In concluding, then, the account of the anatomical characters of the scrofulous caries of the bones which compose the region of the wrist, we may observe, that, as a result of this disease, some of the carpal bones are diminished in size in many cases, while in others they are enlarged. We have noticed some specimens in which two or three of the carpal bones have disappeared altogether, while others have had additional bony growths attached to them. The lower extremities of the bones of the forearm, in almost all the cases, were found rough and scabrous, and increased in bulk, particularly close to the wrist-joint. We, also, after our own examination of the bones of the region of the wrist, have to make the same observation that Sandiford has made relative to the specimens he has preserved in the Anatomical Museum of Leyden, of which he says, — " Omnia hœc ossa levissima sunt."*

Chronic Rheumatic Arthritis of the Wrist. — The wrist-joints, together with the joints of the carpus, are very frequently affected with the disease we have elsewhere, in this work, called " Chronic Rheumatic Arthritis," or rheumatic gout.

When the joints which enter into the region of the wrist are engaged, the fingers are all more or less distorted, and their joints enlarged, as already described. (See Hand.)

Females are more liable to have their wrist-joints affected with chronic rheumatic arthritis than males, and elderly persons more commonly than those who are young; but this disease is to be seen, occasionally, in young persons of both sexes. The disease, when it appears in the wrist-joint, will, in general, be found to affect, symmetrically, the right and left wrist of the patient. The cause of the disease is generally referred to rheumatic fever, and the other articulations of the patient are usually more or less implicated. The patient complains of pain in the joints, particularly at night, of stiffness and rigidity, and of a crackling sensation in them when they are moved. When we come to examine the wrist, it is remarked to present a preternatural convexity on its dorsal aspect, arising from an inordinate quantity of fluid poured out into the synovial sac of the joint. The

* Museum Anatomicum, Sandiford, p. 244. vol. iii.

bursæ of the extensor tendons, as they pass over the carpus, also become distended : these softer fluctuating swellings after a time subside, and the lower extremity of the radius and ulna, where they enter into the formation of the wrist-joint, enlarge; longitudinal ridges of bone can be felt on the back of the radius close to the wrist-joint. The ulna, besides being much hypertrophied at its lowest point, rises abnormally above the level of the dorsum of the carpus. When the disease has been of long duration, the region of the wrist becomes contracted, the back of the carpus and hand presents an attenuated appearance, showing the course of the tendons, and allowing the ridges and prominences of the bone to become visible.

Anatomical Characters. — When we remove the fibrous covering of the tendons which pass by the back part of the wrist-joint and carpus, we find that these tendons are generally deeply imbedded in bony sulci, or grooves. The capsular ligament and other fibrous structures, both on the palmar and dorsal aspect of the joint, seem to be denser and stronger than natural.

On examining the interior of the wrist-joint, we notice that all the articular cartilages of encrustation have been removed from the ends both of the radius and ulna, and that the inter-articular fibro-cartilage, which intervenes between the lower extremity of the ulna and cuneiform bone of the carpus, is removed. In general, at the usual period we are afforded opportunities for making our anatomical examinations, we find but little left of the synovial membrane by which we can judge; but in some cases we have found red synovial fimbriæ exist in the wrist-joint, just as we have noticed this same vascular condition of the synovial tissues to co-exist with the other anatomical characters of the chronic rheumatic arthritis, as they have shown themselves in other articulations which had been affected with this peculiar disease.

Radius. — The lower extremity of the radius is usually somewhat enlarged, and the surface of the bone is scabrous from small exostotic growth. We find the grooves on the back of the radius for the passage of the extensor tendons are preternaturally deepened.

The articular surface of the lower extremity of the radius, where formed for the reception of the summit of the carpus, is usually much hollowed out, and polished from porcellanoid deposition. The outline of the carpal surface of the altered radius is usually studded round with bony granules, or vegetations. When we look to the ulnar side of the lower extremity of the radius, we find the lesser synovial cavity for the reception of the carpal end of the ulna much enlarged, particularly in its antero-posterior diameter. This scaphoid cavity we find also presenting an eburnated surface, and on it fine parallel ridges and grooves are distinctly seen to run in the direction of the rotation of the ulna on the radius in pronation and supination. Where the lower extremity of the ulna confronts the cuneiform bone (the inter-articular fibro-cartilage having been removed), it presents a smooth and polished surface.

Ulna. — The carpal extremity of the ulna is frequently much enlarged, and furnished with exuberant bony growths ; its lowest extremity, where it confronts the cuneiform bone of the carpus (without the intervention of cartilage), is smooth. The part of the extremity destined for rotation on the radius is convex, and oval from before backwards, and of a form, of course, adapted to that of the little scaphoid cavity in the latter, and which is deprived of cartilage, eburnated, and similarly marked with corresponding *parallel* ridges and grooves.

Carpus. — In our anatomical investigations into the state of the hands of those who have long laboured under chronic rheumatic arthritis, we have found the bones of the carpus to be much altered by this disease : in general, the region which these bones constitute will be found to have all its dimensions contracted within a smaller compass then natural. The form of each individual bone is so much changed, that, if found detached, it could scarcely be recognised as a carpal bone. The cartilaginous structure naturally intervening between all the bones is always absorbed.

Cruveilhier has said that, in the anatomical examination of one of his cases of this disease, he found the bones of the carpus confounded together into an irregular mass, so that it was difficult to say the part which each took in the construction of the carpal region.

On examining, anatomically, the bones of the region of the wrist of a patient who had been ten years labouring under this disease, and was under our own immediate observation for almost the whole of this period, we found the bones of the carpus were exceedingly rough on their non-articular surfaces ; each individual bone was found much altered from its normal figure; some were enlarged beyond their usual size, others diminished: the true annular ligament of the carpus, which connected the small bones together on their palmar aspect, and contributed to maintain the arched form of this region, was much shorter than usual.

When we examined each bone, we found that the scaphoid was eburnated on its superior articular surface, where it corresponded to a similar surface on the carpal end of the radius. Below, the scaphoid, instead of contributing, with the head of the os magnum, to form part of the medio-carpal articulation, was really united to the head of the os magnum by true bony anchylosis. The semilunar and cuneiform of the first range were much enlarged. The os lunare, where, by its lower concave surface, it corresponded to half of the head of the magnum, was not, like the scaphoid, united to this last bone, but, on the contrary, both surfaces of the magnum

* *Vide* a work on Chronic Rheumatic Arthritis, by the author, shortly to be published.

and lunar bones, which confronted each other, were covered with an ivory-like polish. The trapezium, where it supported the first phalanx of the thumb, was polished on its pulley-like articular surface. The trapezoides was much diminished in size, and solidly anchylosed with the first phalanx of the index finger. The transverse diameter of the magnum was not one quarter of an inch; and the loss of breadth to this degree accounted somewhat for the abnormal narrowing of the carpus already noticed. The cuneiform was normal, as well as the pisiform. The junction, then, of the magnum with the scaphoid, and the equally solid bony union of the trapezoides with the meta-carpal bone of the index finger, were the only articulations of this region, or, indeed, of the whole skeleton of this individual, which presented specimens of true bony anchylosis. The cause of the eburnation of the surfaces of some of the carpal bones might have been that these bones bore occasionally much of the weight of the man in progression, because he had been much disabled in his lower limbs, and habitually used crutches.

Synovial Tumours of the Region of the Wrist. — Synovial tumours generally present themselves around the joints of the extremities; and the wrist seems especially liable to them. By the term synovial tumours of the wrist, we do not mean those formed by an increased effusion into the proper synovial sac of the radio-carpal articulation, but enlargements constituted by bursæ in this region.

Synovial cysts, called *ganglions*, are frequently seen on the back of the wrist and carpus. They are of a globular form, and, as to size, vary from that of a hazel-nut to that of a walnut. They are usually situated at the level of the medio-carpal articulation in the course of the extensor tendons as they pass to the carpus. These tumours are slightly moveable, indolent, and painless, without any alteration in the colour of the skin which covers them from that which is natural. The contents of these little swellings are found to be synovia of a variable consistency: sometimes it is serous and limpid; occasionally the contents are constituted by a thick transparent jelly. The cyst seems to be formed by the reticular tissue which immediately covers the sheath of the extensor tendons. The part of the cyst which corresponds to the skin is united to it by a layer of very thin cellular tissue, but loose enough to allow of the skin being easily raised up. The part, on the contrary, which is deeply situated reposes in the sheath of the tendons, or the capsular ligament of the wrist, and is firmly connected to them. This union is sometimes so intimate that it is impossible to take away the cyst without interfering with the tendon or the articular capsule.

The thickness of this cyst varies much. Sometimes it is thin and translucent, and it breaks when subjected to but little pressure; at other times its thickness and its texture are such that the most violent efforts cannot rupture it.

We have usually seen this disease in females more than in males; and the cause of the origin of these little tumours in the wrists of the former appeared to us frequently attributable to over-exertion, such as prolonged playing on some musical instruments, such, for example, as the harp or piano.

Whatever may have been the cause for the origin of these encysted tumours, once formed, they for a time increase in a gradual manner; and when they have attained a moderate size, they cease to grow. They sometimes, though rarely, subside spontaneously.

The interior of the membranous sac, in the distention of which, by a glairy fluid, the tumour consists, is smooth and polished. The interior of these cysts *generally* have no communication whatever either with the medio-carpal or wrist-joint itself; but Velpeau says he has seen two cases in which he could easily press the liquid contained in the cyst into the articulation of the wrist if he at the same time gave certain movements to the joint. He adds, that twice he had an opportunity, in the dead body, to show that these cysts communicated with the interior of the joint.

Morbid Condition of the Synovial Bursæ of the Flexor Tendons.—The swellings which these enlarged bursæ constitute, do not present the same regularity of form that ganglions do.

The *cause* of their origin may generally be referred to some great exertion — to a fall or other external violence. I have known, in one case, one of these swellings appear without having been produced by any injury. The constitution of this patient was very decidedly of the rheumatic character.

The species of swelling we are now referring to commences in the synovial bursa which envelopes the flexor tendons of the fingers as they pass beneath the anterior annular ligament of the wrist: the swelling consists of an increased quantity of synovial fluid effused into the cavity of the little sac the bursa constitutes. At first the effusion is small, and the bursa keeps within its normal boundary, behind the anterior annular ligament; but the accumulation of synovia increases by degrees; and then the swelling appears divided into two parts, which are separated from each other by the annular ligament, which seems to form a transverse band which constricts the sac, leaving a tumour above the annular ligament in front of the wrist, and another beneath the level of this ligament in the palm. Pressure on the portion of the sac above makes the synovial fluid pass down into the part of the bursal sac beneath. In these cases the skin preserves its colour and normal mobility, the fingers become somewhat flexed, and there is some difficulty experienced in fully extending them. The patient suffers no pain, but only complains of a numbness and weakness in the fingers, hand, and wrist.

On compressing one of the extremities of this tumour (as, for example, that placed

* Dictionnaire de Médecine, tom. 25, pl. 294.

above the annular ligament), while the fingers of the opposite hand are placed on the other extremity, which is placed beneath this fibrous band, we readily perceive a "*frottement*" which is quite peculiar. This "frottement" is caused by the passage to and fro, under the true annular ligament of the wrist, of small foreign bodies which are not unlike barley grains or those of boiled rice. Their forms are exceedingly variable. They are usually of a white colour, and have a polished surface. They are found in vast numbers in the same cyst, mixed with a more or less considerable quantity of glairy synovial liquid. They are ordinarily free from all adhesions to the parietes of the bursa.

Many theories have been formed as to the origin of these little bodies found loose in the bursa, about the wrist, and elsewhere.

Dupuytren thought he had established the theory that they were hydatids. Laennec and Raspail agreed with him in this view; but Bosc, to whom Dupuytren referred, dissented. The last-mentioned naturalist looked upon them as concretions of lymph of an adipocerous nature. He says, "They are not to be considered as 'hydatids,' because they have not given any sign of life on escaping from the cyst." On dividing these bodies, he found them uniform throughout, whilst that of hydatids are always hollow; and again, because submitted to a strong lens, they have appeared to him to be nothing else than an inorganic mass, whether he examined them when recent or dried."

Sir Benjamin Brodie's opinion now seems generally to prevail. It is adopted by Nelaton * and other French physiologists: — "There seems to be no doubt but that these loose bodies have their origin in the coagulated lymph which was effused in the early stages of the disease; and I had opportunities, by the examination of several cases, to trace the steps of their gradual formation. At first the coagulated lymph forms irregular masses of no determined shape, which afterwards, by the motion and pressure of the contiguous parts, are broken down into small portions. These by degrees become of a regular form, and assume a firmer consistence, and at last are converted into the oval bodies above alluded to." †

Examples of these have been seen in the synovial sheaths of the radial extensors as well as on the back of the wrist in the course of the extensors of the fingers. But it is, nevertheless, certain that the bursa of the flexor tendons, situated in front of the wrist and carpus, and behind the true annular ligament of this region, is the special locality in which these foreign bodies are most frequently found.

Painful Crepitation of Tendons around the Wrist. — We notice, sometimes, around the carpus and in the inferior extremity of the forearm, a swelling which is peculiar in this, that, whenever the tendons around which the swelling forms are moved, there is thereby elicited a very peculiar crepitation.

This crepitation is noticed along the course of the extensor carpi radialis longior and brevior, and in that of the long abductor and short extensor of the thumb. This swelling is not globular, nor is it so well defined as a ganglion, but may be said to represent in its form a portion of a spiral which, parting from the dorsal surface of the forearm, soon turns round the external part of the radius to gain the root of the first metacarpal bone.

This swelling seems to be of an inflammatory nature, and is occasionally accompanied with a superficial redness of the skin; and pressure on this part becomes painful to the patient. If the surgeon places his thumb or fingers on the postero-external surface of the forearm, near to the wrist-joint, where the oblong swelling exists, and at the same time desires the patient to move the hand by flexing and extending the wrist-joint, or exert the muscles, the peculiar crepitation which characterises this lesion is soon perceived.

It is not very easy to convey an idea of this crepitation; but it has been compared by many to that produced by the crushing together, with our fingers, portions of finely powdered starch, or to the effect which we feel produced when we walk over snow. When once recognised, it is perceived to be quite different from that crepitation which is produced by the movement on each other of the fragments of broken bones or the rubbing together of roughened articular surfaces. This disease has for its anatomical seat the fibro-synovial sheaths of the tendons already mentioned. These extensor tendons, namely, the two extensor radialis longior and brevior, as well as those of the long abductor and short extensor of the thumb, cross each other, each in special sheaths or canals formed on the back part and external edge of the lower extremity of the radius; and if inflammation attack the lining membrane of these fibro-synovial sheaths, it is plain that, in this anatomical arrangement, there may be seen many circumstances to favour the development of this crepitation.

This affection has not, we believe, ever been observed to have come on spontaneously, but generally to have arisen from some violent and continued efforts of the wrist and hand.

It has been noticed in soldiers and masons, and in those who are in the habit of twisting the forearm, as in the act of forced pronation of the forearm of washerwomen in wringing clothes. The tumefaction, the swelling, pain and heat, and the crepitation also, once commenced, augment generally for four, six, or eight days; and if the patient be guilty of any imprudence, the evil is maintained to the same degree even to the twelfth or fourteenth day, after which it ordinarily terminates in resolution.

(*Robert Adams.*)

* En 1819 M. Brodie donna une interprétation satisfaisante de leur étiologie en les rattachant aux épanchemens séro-albumeux. (Nelaton, Pathologie Chirurgicale.)

† Brodie on the Diseases of the Joints.

Addendum to the Article Urethra.

*** In justice to a distinguished anatomist and surgeon, Mr. Henry Hancock, whose claims to priority of the discovery of unstriped muscular fibres in the urethra were overlooked by the author of the article Urethra, the Editor thinks it right, with the assent of the author of that article, to insert the following paragraph, drawn up by Mr. Hancock, as an addendum to it: —

The urethra itself is a membranous tube, consisting of mucous membrane, presenting villi on its free surface for the most part arranged in rows, some being conical, others tuberculated, covered by epithelial scales. The outer surface of the urethra is closely invested by cellular tissue, external to which is found a layer of organic muscular fibres, similar to, and in fact continuous with, the muscular coat of the bladder. This last-named structure consists of two layers, an internal and an external; the external passes forwards on the outside of the prostate gland; the internal, on the contrary, accompanies the mucous lining of the bladder, when it becomes urethral through the prostate gland, forming a covering of involuntary muscular fibre to the canal in its passage through the gland. In front of the prostate, the two layers of muscular fibre unite and invest the membranous portion of the urethra, where they may easily be distinguished from the voluntary muscles of the part. Reaching the bulb they again separate into an internal and an external layer; the internal continues forwards to the orifice of the urethra, lying between that canal and the corpus spongiosum; the external passes on the outer surface of the corpus spongiosum, separating it from its fibrous investment, to which the fibres adhere pretty closely. These latter, like the internal, are continued forward to the orifice of the urethra, and in their course they invest the spongy portion of the bulb, the urethra, and the glans penis, entering very largely into the formation of the peculiar structure found at the orifice of the urethra, and which appears to consist almost entirely of involuntary muscle and cellular tissue. Hence, the corpus spongiosum urethræ lies between two layers of involuntary muscle, the one separating it from the urethra, the other from its fibrous investment; and this arrangement obtains wherever the corpus spongiosum exists, whether the quantity thereof be small or great. On the under and lateral portion of the urethra, where the quantity is abundant, the corpus spongiosum lies between two layers of involuntary muscular fibre. On the upper surface of the urethra, where the quantity is comparatively small, the same arrangement may be observed, whilst at the glans, which is not formed merely by increased development of the spongy tissue, but also by a folding back, as it were, of the spongy tissue over the corpora cavernosa, we find these muscular layers multiplied.

ANALYTICAL INDEX

TO THE

FOURTH VOLUME.

* See note to this article, page 231.

THE END.

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