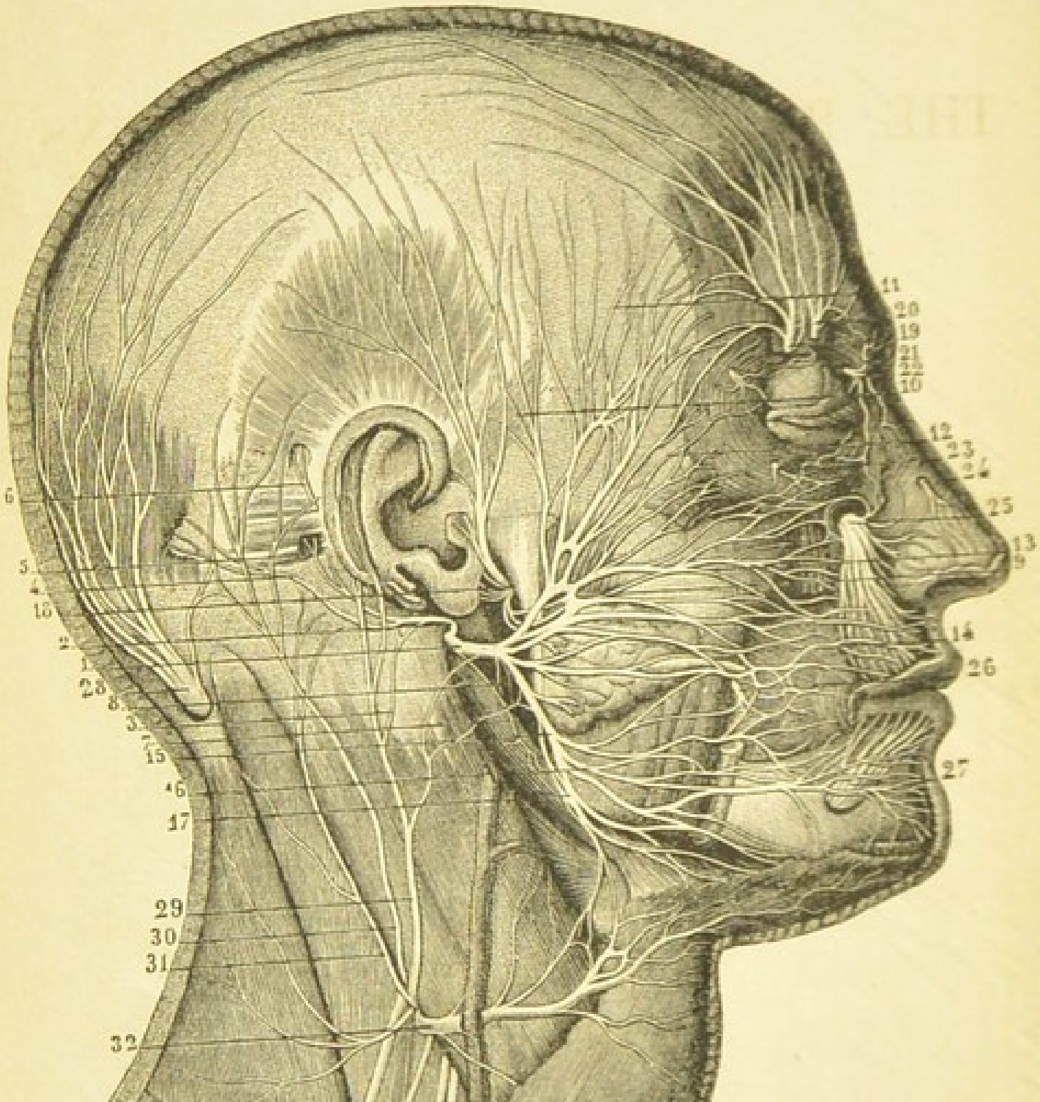
ANIMAL PHYSICS.



NERVES OF THE FACE.

To M. Leveillé
from the author

42550

ANIMAL PHYSICS;

OR,

THE BODY AND ITS FUNCTIONS,

FAMILIARLY EXPLAINED

By DIONYSIUS LARDNER, D.C.L.,
Formerly Professor of Natural Philosophy and Astronomy, in University College, London.

WITH FIVE HUNDRED AND TWENTY ILLUSTRATIONS.

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In the composition of this volume the Author has attempted to render a department of natural science, hitherto exclusively confined to the medical profession, accessible to all persons of ordinary education. The several subjects, to the exposition of which the volume is devoted, have, accordingly, been treated so as to be suited to readers of either sex and of any age.

Since such a work, proceeding from the pen of one not of the medical profession, might be supposed to be liable to anatomical or physiological inaccuracies, the Author has induced several professors who feel an interest in the popular diffusion of this branch of science, to read the sheets before being finally sent to press, and has gratefully availed himself of many suggestions arising from such revision.

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ERRATA.

Page 38, paragraph 65, line 25, *omit* "towards the temples."

Page 41, paragraph 70, line 14, *for* "C" *read* "S."

Page 46, paragraph 75, line 15, *for* "canine" *read* "canines."

Page 196, fig. 179, *for* "Carrabus" *read* "Carabus."

Page 219, Note ought to be * "Edwards."

Page 234, ,, ,, ,,

Page 409, paragraph 580, line 1, *for* "comprising" *read* "composing."

Page 601, paragraph 962, line 15, *for* "then are" *read* "is then."

Page 602, fig. 444, *for* "Sappey" *read* "Breschet."

Page 603, paragraph 966, line 9, *for* "great" *read* "greatly."

Page 612, paragraph 987, lines 2 and 3, *for* "and on the natural larynx dissected ; from the dead subject as well as observations," &c., *read* "and on the natural larynx dissected from the human subject ; as well as observations," &c.

Page 638, line 6, *for* "large" *read* "larger."

ANIMAL PHYSICS.

CHAPTER I.

GENERAL VIEW OF THE ANIMAL ORGANISATION.

1. The diffusion of knowledge is ever commensurate with the progress of discovery. As the boundaries of science are enlarged the craving of the general mind for the acquisition of it is stimulated, and this appetite is rendered more irresistible by the contemplation of the vast benefits and augmented powers conferred upon the arts of life by every fresh advance in scientific researches. Who that beholds the prodigious extension given to metallurgic industry by the discoveries of mineralogists and chemists, can resign himself to absolute ignorance of the materials of which the globe is composed, and the elements of which bodies are constituted? Who that contemplates the marvellous history of the earth revealed by geologists can rest in contented ignorance of the science which has taught us to interpret the characters written upon its crust, in which its state, myriads of ages before it became the habitation of the human race, is recorded?

But of all the stores of knowledge thus spread before us, there are surely none which should more pique our natural curiosity than those which open to us a view of animated nature. In these we have, so to speak, a selfish interest. So far as relates to our material being, we are ourselves one of the order of animals, among which we hold the highest place. Our organisation includes the most exalted specimen of nature's work exhibited to us here below. In no department of science has so extraordinary a body of knowledge been evolved. In none have results been obtained manifesting in a more striking manner the attributes of the Great Maker of All, than in the provisions made for the maintenance and continuance of the

species which inhabit the earth, and for the moral and physical supremacy of man over them.

In all educational institutions established within the last half-century, provisions have accordingly been made for the supply and enforcement of this branch of general instruction. The regulations of the University of London, as well as those of similar establishments in other enlightened countries, require an acquaintance with the structure and functions of the animal, and more especially of the human, organisation, as a qualification for the first degree claimed by a student, a degree which signifies the acquisition of the elements most essential to a liberal education. This does not mean, however, that every youth sent forth into the active walks of life is to be a naturalist, anatomist, or physiologist. To sound the depths of these sciences would require time and labour incompatible with the other acquirements which must be attained by such students, and would include a multitude of details useful to those alone who propose to make these sciences their specific study. It is not necessary to a liberal education to be able to pronounce upon the nice distinctions which separate species from species, nor to trace the course of each artery and nerve which traverses the organs of the body. Such details would encumber the memory of the general student, without leaving upon it any durable or useful traces. The knowledge which is desired is of another kind. The general structure of the human body and its organs, the principal functions by which they are sustained and nourished, the most striking relations and analogies between them and the corresponding organs of inferior species, the manner in which the functions are exercised, and the relations between the varying structure of the organs and the habitudes of life of the species to which they belong, constitute knowledge which once well and soundly acquired can never be forgotten, and which, while it suffices for those whose pursuits in life do not necessarily connect them with the prosecution of the natural sciences, serve as the base of the special studies of those who engage in professions, with which these sciences are necessarily connected.

Such is the purpose which the present volume pretends to attain. While, however, these are the immediate and only direct subjects of instruction included in its pages, other indirect, though scarcely less important, advantages to the student may be hoped for. The influence which the study of natural science exercises upon the intellectual faculties merits

serious attention. The course of investigation through which the mind is conducted in such studies habituates it to ascend from effects to causes, yet never advancing a step without submitting the deductions of reason to the severe tests of experiment and observation. While such studies lead, therefore, to a habit of lofty speculation, they never permit the imagination to wander, inasmuch as the material verification is rigorously placed in juxtaposition with the speculative hypothesis. This, in a word, like every other branch of natural history prosecuted on just principles, exercises the mind better than any other in those methods of reasoning, without which all investigation is laborious and all exposition obscure.

Many works have been composed by eminent writers on subjects analogous to those treated of in the present volume, with the express and exclusive view of illustrating the divine attributes by the exposition of the never to be too much admired provisions made in the organised world for the well-being of the creatures which inhabit it. Although such has not been the object with which these pages have been composed, the reader will soon perceive that it has not been overlooked, and it may be hoped that such reflections expressed when they arise naturally out of the exposition of the phenomena, will not have the less force, inasmuch as they are not obtruded in the mere spirit of advocacy.

The relations between the phenomena developed in the animal organisation and the laws of physical science are insisted on more especially, and the structure, organisation, and functions of the animal body, are viewed as beautiful examples of the play of the same principles which are brought into action in an infinitely less perfect manner in the artificial contrivances of man, more frequently than is generally the case in treatises on natural history.

2. **Structure of the Body.**—The animal body consists of solids and fluids. The solids, in all except the lowest species, are, some hard and compact; others soft, flexible, elastic, or tough, in various degrees. The hard and compact parts serve as the frame-work and support for the others. They give form and external character to the body, and precision to its motions. In certain inferior species, these hard parts constitute the external covering, and enclose and protect the softer and more delicate organs. In such cases they are called the *shell*.

In all the higher species, however, without exception, the hard and compact frame-work of the body is within its exterior covering, the softer parts being, some attached to and supported by it, as well outside as inside, and others deposited in suitable cavities adapted for their conservation and the special exercise of their respective functions. The hard and compact parts, which thus form the frame-work of the body, are in such species called the *bones.*

3. The principal fluids are included in central reservoirs, from which they are propelled by a suitable apparatus to the extremities, and driven back from the extremities to the central reservoirs through a system of flexible tubes, which vary in their calibre from the large conduits leading from and to the central reservoirs to capillary tubes so minute as to be microscopic. The fluids thus kept in circulation distribute to all parts of the system whatever is necessary to restore waste in the adult, and to supply growth in the young.

It will be apparent that in such an organism must be found the play of the principles of every branch of physical science. The bones are constructed and moved upon the same principles of mechanics as govern all machinery. The fluids are propelled and distributed by an apparatus illustrating the principles of hydrostatics and hydraulics. The organs of respiration illustrate the principles of pneumatics ; the sense of vision is exercised by an optical instrument of admirable perfection ; and the sense of hearing and the organs of voice are examples of the most perfect acoustic apparatus.

4. **Skeleton.**—The assemblage of bones, in their natural order and juxtaposition, is called the *skeleton*, from the Greek word σκελλω (skello), *to dry*, the bones thus exhibited and combined being previously stripped of the flesh and dried.

5. **Mechanism of the Skeleton.**—The motions of which different parts of the body are susceptible have so close an analogy to those of certain parts of machinery, that it might be naturally supposed that the moving parts should be in both cases connected by the same expedients. Thus, for example, the motions of the arm upon the shoulder, and of the thigh upon the hip, have a play and limits altogether similar to that produced by the ball and socket-joint, while the motions of the fore-arm at the elbow, and the leg at the knee, are perfectly similar to that of the hinge or cradle-joint. Never-

theless, although the mechanical connection of these members has something in common with the expedients referred to, they are far from being identical with them. In machinery, the moving parts are generally connected by inflexible pieces; thus, for instance, the parts connected by a ball and socket-joint are firmly held together by the enclosure of the ball in a hollow spherical cavity somewhat greater than a hemisphere. As the ball cannot pass through an opening having a diameter less than its own, it cannot escape from such a socket. If the socket were only equal to, or still more, if it were less than a hemisphere, the ball would be capable of moving in, but would not be retained by it. In like manner, two parts connected by a hinge are retained in their relative positions by a rod, pin, or wire passing through a hole made in the common centre of the two pieces which more immediately form the joint. If this rod or pin were withdrawn, the parts would still be capable of moving in the manner permitted by the joint, but would not be retained in their proper juxtaposition.

6. If the bones composing the skeleton were held together at their several joints by mechanical expedients similar to those used in machinery, it would follow that, were it possible suddenly to divest them of all the flesh and softer parts, leaving nothing but the hard and compact substance properly called bone, the skeleton would still maintain all its parts in their proper relative positions, and each would still be susceptible of the same motions; for by the supposition, the joints being all formed by mechanical connections similar in material to those of the bones themselves, would not be affected by the removal of the softer parts with which they were previously surrounded, and to which they gave support.

7. Such, however, would not be the case. On the contrary, the sudden dissolution and removal of all parts of the body not strictly *osseous* would be instantly followed by the complete dismemberment of the skeleton, the various bones of which, with a few exceptions which will be noticed hereafter, would fall asunder by their own gravity.

8. It appears, therefore, that if the skeleton afford support to the softer parts of the system, these latter must reciprocally give support to it. Neither could maintain their natural position unsupported by the other.

9. **Joints.**—The joints, or *articulations* as they are technically called, unlike those in artificial mechanical combinations,

are formed not by sockets like those of ball and socket-joints; nor by rods or pins like those of cradle-joints; nor, in short, by any expedients commonly used in the formation of joints in machinery, but by certain tough, fibrous, and elastic bands inserted firmly in the surfaces of the parts to be united; in such a manner, nevertheless, as to allow free play to the moving parts within the prescribed limits. These bands are called *ligaments*, from the Latin word LIGO, *I tie*. It will, therefore, be easily understood why upon the removal or dissolution of such means of connection the bones would fall asunder.

If no other expedient, however, were provided in the mechanism of the joints, it is easy to see that the body, subject to the incidents to which it must necessarily be exposed, would be gradually deteriorated and soon destroyed. The surfaces of the bones, connected as described above, would be pressed one against the other by the incumbent weight of all that part of the body situated above the joint; and upon every motion of the joint the surfaces in contact would rub one against the other with a degree of friction proportionate to the force by which they are pressed together; and no matter what might be the character of their surfaces, such friction would gradually abrade and wear away the bone.

10. But independently of this, the connecting ligaments being more or less elastic, the contiguous surfaces united by them are not always in contact, and are more or less separated according as, by the varying attitude of the body, the parts united are released from the pressure which urges them together. It would consequently happen that, in the frequent incidents of bodily motion in which the members are subject to slight shocks or concussions, as, for example, in rapid walking, running, or still more, in vaulting or leaping, the joints would rattle, the contiguous surfaces impinging on each other, as hard bodies do when they accidentally come into collision. Besides other injurious effects which are sufficiently obvious, the surfaces of the bones at the joints would be chipped and cracked, and the mechanism of the system soon utterly destroyed.

11. Let us consider for a moment how similar injurious effects are obviated in mechanical contrivances.

If the carriages of a railway train, for example, were connected one with another by chains or cords more or less flexible, they would enter into violent collision one with another, not only when the train would suddenly stop, but on

the occasion of every sudden change of speed; the vehicles thus striking against each other, the parts subject to such collision would soon be broken and destroyed. All objects transported by the vehicles would share, more or less, in these shocks consequent upon every change of momentum, and for the transport of passengers the carriages would thus be rendered intolerable. Now, these evils are effectually prevented by attaching to the ends of the carriages soft cushions, called buffers, behind which are springs to give them increased elasticity. The shocks produced by the causes above mentioned are broken and mitigated so as to be rendered scarcely perceptible, save in extreme cases, by these expedients—the momentum of the shock being expended upon the cushion and spring.

A similar expedient is applied in the skeleton. A coating or cushion of a tough, fibrous, and elastic substance called *cartilage*, interposed between the bones at the joints, breaks the force of collision in precisely the same manner as do the buffers established between the successive vehicles composing a railway train.

12. **Interosseous Cartilage.**—In some cases where the two bones jointed together are not intended to move in contact with each other, but only to change their relative position within small limits, so as to give a certain flexibility to their combination, the surfaces connected are flat, or nearly so, —equal in magnitude, similar in form and parallel. The cushion of cartilage interposed, is firmly attached to both of them, so that the surfaces which it unites admit of no lateral or sliding motion. In this case the interosseous cartilage serves a double purpose. Its softness and elasticity break the force of collisions, and its flexibility allows the two bones it connects to be inclined to each other in any direction within certain limits, such inclination being attended with a compression of the interposed cartilage on the side towards which the inclination takes place, and an extension on the contrary side. It is evident that the degree of flexibility, permitted by such a joint, will vary with the thickness of the stratum of interposed cartilage.

The cases, however, are much more numerous in which a greater play being allowed to the bones, their surfaces must move with a sliding motion one upon the other. The mechanical conditions, necessary to give efficiency to such a joint and permanency to its action, are much more numerous and complicated. As in the class of joints above described, a coating of interosseous cartilage is provided to break the force of collisions.

But as the mere elasticity and flexibility of such cartilage would be altogether insufficient to allow of the extensive play required to be given to the bones, the surfaces must move freely one upon the other, and consequently the interposed cartilage cannot be as in the former case a single stratum with its opposite surfaces adhering to the bones. Two separate and independent strata, or coatings, are therefore provided in these cases—one attached to each osseous surface. These completely intercept the contact of the bones, and the surfaces which really move upon each other are those of the cartilaginous coating, and not those of the bones.

13. **Friction of Joints.**—As the surfaces moving thus in contact are subject to a constant change of relative position, it is obviously necessary, not only that one surface should correspond in form with the other in one position, but that they should do so in all the positions which they are capable of assuming. This is a condition which, according to the principles of geometry, can only be fulfilled by giving to the surfaces a form which is either plane, cylindrical, or spherical, since the only lines which can move upon one another, so that every point of them shall be in mutual contact, whatever be their position, are the straight line and the circle. Two plane surfaces, therefore, can slide evenly one upon the other. Two cylindrical surfaces, one of which is convex and the other concave, can also slide evenly upon each other, all their parts being constantly in mutual contact, provided they have the same radius and a common axis, and provided the motion take place round the axis of the cylinder, and not otherwise.

Two spherical surfaces, one of which is convex and the other concave, can, in like manner, slide evenly upon each other, every point of the one being in contact with the other, provided that they have the same radius and a common centre, and provided that the motion take place only round that centre, whatever may otherwise be its direction.

It will be seen hereafter, that these conditions are fulfilled in each case by all the joints in the animal economy which are composed of surfaces moving one upon the other.

Although these conditions, however, provide against the injurious effects of collision, it remains to show how those which would attend the mutual friction of the cartilaginous coatings are prevented. In the first place, these coatings are so constituted as to be susceptible of smooth and even highly polished

surfaces. Where the surfaces of the bones are plane and parallel, the coatings are of uniform thickness ; but, where the surfaces are concave and convex, the coating of the concave surface is thinner towards the centre than towards the borders ; while, on the contrary, the coating of the convex surface is thinner towards the borders than towards the centre ; the result of which is, that in the normal position of the bones the sum of the thicknesses of the two coatings is uniform.

14. **Adhesion of Joints.**—It is not enough, however, that these interosseous surfaces should be endowed with the highest degree of smoothness, polish, and uniformity of figure. The very perfection of these qualities, combined with the force with which the joints are in many cases loaded, would even in the absence of friction produce a degree of adhesion between the surfaces, similar to that which takes place between two surfaces of polished metal which are brought into close contact ; an effect familiar to all workmen in metal, and called the BITE. In short, this adhesion would not only obstruct, but in most cases completely arrest the motion of the bones thus connected, though all the prescribed conditions should be fulfilled in the strictest manner.

15. **Synovia, its Uses.**—In the practical construction of machinery, the obstruction arising from adhesion is removed by the lubrication of the surfaces which form the joint by some suitable liquid or semi-liquid substance. A similar expedient is accordingly applied for the same purpose in the animal economy. Every joint in which the surfaces move upon each other is provided with an apparatus by which a certain viscid glairy liquid is secreted, resembling in its physical qualities the white of egg, and hence called SYNOVIA. This liquid is constantly poured over the surfaces of the cartilaginous coatings, so as to produce the same effect upon them as oil does between the axle and the box of a carriage-wheel. In fact, this liquid, strictly speaking, by its interposition between the cartilaginous surfaces prevents their mutual contact; and its molecules, being infinitely small and infinitely smooth spherules, have the effect of the most perfect imaginable friction rollers. By this admirable provision, therefore, the obstructions which would arise from both friction and adhesion are removed, the interposition of the polished rolling molecules removing those of friction, and the prevention of contact removing the possibility of adhesion.

Anatomists are not completely agreed as to the nature of the apparatus by which this lubricating fluid is secreted ; but they have designated it generally by the name of the *synovial membrane.*

The beneficial effects of synovia are not, however, confined to the joints, but extend generally to every part of the system, where surfaces move upon each other ; and, as in the change of position of the bones, the ligaments which connect them at the joint must move, more or less, upon the surface of the bone, their surfaces are likewise lubricated by the synovia.

The synovial membrane surrounds the joint on every side, and thus contributes in the most effectual manner to maintain the bones in contact, by excluding from the space between them all surrounding fluids which would be exposed to the atmospheric pressure. The consequence of this is, that any attempt to separate the bones at the joint would necessarily be resisted by the whole force of the atmosphere. To be assured of this, it is only necessary to attempt to disjoin the bones of a dead subject; the resistance will be found to be considerable. But if the synovial membrane surrounding the joint be punctured, so as to admit the air, the dismemberment will be comparatively easy.

16. **Muscles.**—The apparatus by which the bones are held together being described, it remains to show how those movements of which they are severally susceptible are imparted to them. The bones themselves are merely passive instruments ; and the ligaments by which they are connected, the forms given to them at the joints, the cartilaginous coatings, and synovial apparatus, are provided respectively for facilitating but not at all for originating their motions.

The apparatus by which the motions are immediately produced, are fibrous bands and masses of flesh called *muscles*, which constitute that part of the animal body which when used for human food is called *meat.* With the visible fibrous structure of the muscular tissue every one must be familiar.

Muscles consist of fibres ranged generally side by side, parallel to each other. They are extended between the bones, to one or both of which they are intended to impart motion ; or, as in the face and eye, one end only is attached to bone. The muscle itself, however, is not immediately connected with the bone. At its extremities it gradually takes the form of tendinous fibres, totally different in their physical character from the fibres of the muscle itself.

17. **Tendons.**—These tendinous fibres are sometimes collected into a single cord called a *tendon*, which is inserted in the bone so firmly that before it can be detached from it the bone itself would be broken.

Sometimes their extremities are spread out on a line of greater or less length; and, instead of being inserted at a single point of the bone, are attached to it along a line of corresponding extent. In such cases, the tendinous connections of the muscles with the bone are called aponeuroses.

18. When two bones are connected by a muscle, it generally happens that the normal action of the muscle is to impart motion to one only of the two bones. In that case, the bone which it moves is to be regarded as a lever,—the point where the tendon of the muscle is inserted being the point of application of the power, and the point where the two bones are united being the fulcrum. It is customary to denominate the point where the tendon of the muscle is attached to the bone to be moved, the *insertion*, and the point where the other tendon is attached to the connected bone, the *origin* of the muscle. This distinction, however, cannot always be rigorously observed, inasmuch as in some cases the muscle acts indifferently in imparting motion to either bone.

19. The property by which the muscles move the bones is a power of contraction, which constitutes their peculiar and distinguishing character, and in which no other parts of the animal organisation participate. By this power they are enabled to diminish their dimensions measured in the direction of their fibres; and, since these fibres are extended between the origin and the insertion, it follows that by such a contraction the tendon of the insertion is drawn towards the tendon of the origin, and with it necessarily the bone in which the insertion is made, is drawn towards that in which the tendon of the origin is implanted.

This contractile power of the muscle may be compared to the tension of a spring, and the tendons to the straps by which the spring is connected with the object upon which it acts. Like the straps, the tendon or aponeurosis has no contractile power, and produces no effect whatever upon the motion of the bone. It is merely the instrument by the intervention of which the contractile elasticity of the muscle is conveyed to the bone, exactly as the elasticity of the springs upon which a carriage is suspended is conveyed to the body by the straps which connect the one with the other.

The contractile force of the muscles has no reaction. There is no corresponding extensile force. When by the contraction of a muscle one bone has been drawn towards another, it will be held in that position so long as the contraction continues. But as this contraction absorbs a certain amount of animal force, and as this absorption is *cæteris paribus* in the exact proportion of the continuance, it would necessarily happen that after a certain interval the animal energy which produces the contraction would relax, and the bone upon which the contraction had acted being liberated from the force to which it was previously subject, would be free to move in obedience to any other force which might act upon it. But, if no other force acted upon it, the relaxed muscle would have no power to move it back to its original position.

It follows, therefore, that in all cases in which a bone is moved alternately in contrary directions, the action of two muscles placed on opposite sides of it is necessary.

20. The two muscles which thus exert opposite actions are said to be *antagonistic.*

It is evident from what has been stated, that the points of origin and insertion of two antagonistic muscles must be placed on opposite sides of the bone on which they act.

Since a muscle can impart no other motion to a bone than that which is determined by the relative positions of its points of origin and insertion, it follows that a bone which is susceptible of many different motions with relation to the bone with which it is connected, must be moved by the action of as many different muscles.

When, as frequently happens, two different muscles conspire to impart a certain motion to a bone, they are said to be *congenerate.*

It has been ascertained that when a muscle is contracted between its origin and insertion, it undergoes no real diminution of volume, since it suffers an increase of dimension in a direction transverse to that of its contraction, which is commensurate with the decrease of its dimension in the latter direction. Any one can convince himself of this by observing the effects produced by the contraction of the muscles of his own limbs. If the hand be raised to the shoulder so as to bend the elbow-joint to an acute angle, the muscle producing this motion, which has its insertion in the fore-arm and its origin in the arm, will be gathered into a voluminous lump on the arm between the shoulder and the angle of the elbow, a

lump which can be distinctly seen and felt, and which presents a remarkable appearance in persons of strong muscular development.

21. **Muscular Force.**—Anatomists and physiologists have not determined with certainty the mechanical change by which muscular contraction is produced. When the muscular tissue is submitted to a microscope of moderate magnifying power, one, for example, of five or six times the linear dimensions, each fibre is found to consist of a number of fasciculi, each similar to the original fibre. In fig. 1, A represents a small portion of a

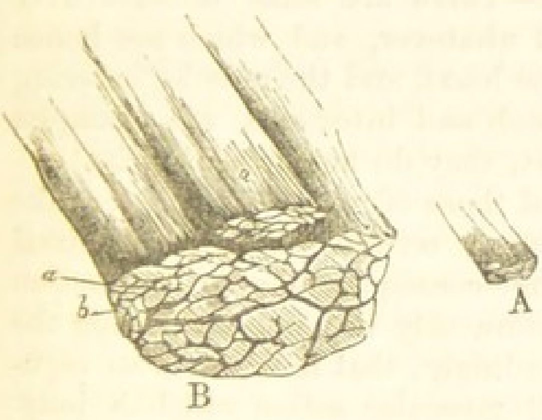


Fig. 1.

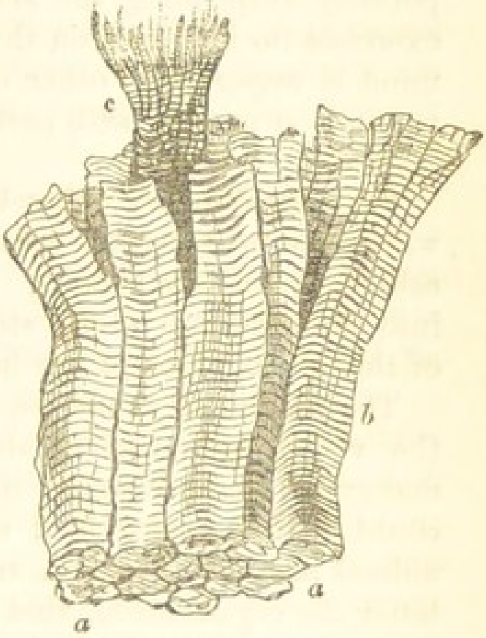


Fig. 2.

muscle in its natural size, cut transversely at its extremity. B represents the same object magnified five times in its linear dimensions, the component fibres of which it consists being rendered apparent. Fig. 2 represents a part of a muscle submitted to a much higher magnifying power, in which the structure of each separate fibre is shown as marked by a series of transverse striæ. The terminal section is shown at *a a*, the transverse striæ at *b b*, and a single fibre split into its component fibrillæ at *c*.

When muscles have been examined with the microscope in the process of contracting, their transverse striæ have been observed to approach each other, an effect which would necessarily be accompanied by a corresponding diminution of their dimensions in the direction of their fibres.

The contractile power of the muscles which have been described can, in general, only be called into action by the dictate of the will. Hence they are called *voluntary muscles*, and examples of them are presented by the muscles which impart motion to the principal members of the body. Thus, the muscles by which the legs or arms are moved, can only be brought into play by the operation of the will. There are some muscles which are, to a certain extent, subject to the will, but also act independently of it. The muscles which move the chest in respiration present examples of this class. The will has the power of accelerating, retarding, or even of temporarily suspending the act of respiration ; but when the will exercises no influence on the organs of respiration, as when the mind is engaged in other objects, or in sleep, the process of respiration goes on with perfect regularity.

22. **Involuntary Muscles.**—There are some muscles over which the will has no control whatever, and which are hence called *involuntary muscles.* The heart, and the muscles entering into the structure of the stomach and intestines, are examples of this class. Except the heart, they do not present striæ.

The involuntary muscles, and those of a mixed character, like the voluntary muscles, absorb a certain amount of animal energy by their contraction, and consequently such contraction could not be maintained continuously without exhausting the animal power. We find, accordingly, that nature has so regulated the organisation, that all muscular action which is independent of the will is intermitting, so that the intervals of muscular repose or relaxation are, on the whole, equal to those of muscular tension. The heart of an animal beats incessantly, sleeping or waking, during the continuance of its vitality ; and this action may continue in man even for a century. The muscles, however, which produce it are never in a state of tension for more than a moment, so that they are enabled to recover their energy in the alternate intervals of their relaxation.

23. **Blood.**—The fluid by which this system of bone and flesh is nourished is the blood, which, having its fountain in the heart, is propelled from thence by the strong muscular action of that organ through a system of flexible tubes called *arteries*, which, like the trunk and branches of a tree, are of large calibre at their point of origin, and grow gradually less as they

ramify through the system, until they terminate in another set of pipes called, from their extreme minuteness, *capillaries*. From thence the nourishing fluid passes into another system of tubes, called the *veins*, through which it is carried back to the heart. The form and distribution of the veins is something like that of the arteries, their trunks entering the heart, and their minute ramifications being connected with the capillaries. While the blood, however, passes in the arteries from the trunks to the branches, it passes in the veins from the branches to the trunks.

In passing from the arteries to the veins through the capillaries, the blood undergoes a remarkable change in its physical qualities. Having given up its nutritious elements to the organs through which the capillaries conduct it, it is carried back by the veins to the heart, to receive a fresh supply of the nutritive constituents. Its colour is also visibly changed, the arterial blood being bright red, and venous blood blackish red.

24. **Lymph and Chyle.**—Another system of tubes originating in all parts of the body consists, like the veins and arteries, of ramifications and trunks conducting from every part of the body, but more especially from the intestines, to the heart, a fluid which in some parts is colourless and in others whitish. This fluid is called *lymph*, and the vessels which thus conduct it are called *lymphatics* ; that which is taken up from the intestines has the name of *chyle*. As in the veins, the lymph flows from the branches of the lymphatics to the trunks. These trunks discharge their contents into the venous trunks at points near those at which the latter enter the heart ; so that after the confluence of the lymphatics with the veins, the contents of the latter are a mixture of venous blood and lymph. This lymph contains a part of the nutritive elements by which the venous blood is renovated.

25. **Circulation.**—After this mixture of blood and lymph is discharged into the cavities of the heart by the venous trunks, it is again propelled to the lungs from the heart by the muscular force of that organ though a system of flexible pipes, called the pulmonary arteries. In the lungs this fluid mixture of blood and lymph is acted upon by the air received into the latter organs by respiration ; and here it undergoes the final change by which it recovers all its nutritive qualities, and is reconverted into bright red arterial blood.

26. From the lungs, after undergoing this change, this blood is propelled through another set of pipes called the pulmonary veins back to the heart, where it is received into another cavity, from which it is driven as before through the arteries into the capillaries, and back to the heart through the veins.

Such are the phenomena which constitute what is called the *circulation of the blood.*

27. **Respiration** is a function intimately connected with circulation. The atmospheric air drawn into the lungs in breathing penetrates into the air cells of these organs ; and there acting on the blood through the tissues, some changes of great vital importance take place. The oxygen of the atmosphere is absorbed, and the carbonic acid, with which the venous blood was charged, is liberated. This double effect produces the final change by which the blood recovers its arterial character. The air we expire, consequently, in respiration, being deprived of the chief part of its oxygen, is charged with a certain quantity of carbonic acid.

28. Circulation and respiration are therefore the phenomena which constitute the proximate source of nutrition. The arterial blood, passing through the system, deposits in every part of it the nutritive principles, and receives in exchange a portion of what the body rejects. The lymphatics, collecting the nutritive lymph from various parts of the system, pour it into the venous blood, with which it is carried to the lungs, where the venous blood gives up the noxious elements which the organs had rejected and thrown into it, these noxious elements being expired in respiration, and where it receives the oxygen of the atmosphere, which is necessary, combined with the lymph, to reconstitute its nutritive power.

29. **Nerves.**—In assigning the muscular apparatus and its contractile power as the proximate agency to which the motions of the body are to be ascribed, we have advanced one step, but only one, to the origin of these motions. What, it may be asked, induces those muscular contractions which are themselves the cause of the bodily motions ? What conveys the dictates of the will with such promptitude and precision at each moment, to any one, or to many at once, of several hundred muscles distributed throughout the body ?

This wonderful effect is produced by the still more wonderful apparatus of the nerves. These complicated threads, originating

in the brain, diverge in thousands of directions from that as a centre to every part of the system. Their main trunk, proceeding from the back of the skull down a central perforation in the backbone, throws out on the one side and the other, through lateral orifices, innumerable ramifications, which extend to every part of the body.

30. Each muscle receives one or several nerves, each of which is enclosed in a sheath or covering called a *neurilemma*. These nervous filaments, thus enclosed, traverse every part of the muscle in directions parallel to each other, and perpendicular to the muscular fibres. The greater part of them pass on to other muscles, and are inoperative relatively to that which gives them passage. But some terminate in the muscle, or, according to the opinion of some physiologists, after looping themselves upon the muscular fibres, they rejoin the filaments by which they arrived at the muscle, and thus return to the brain.

31. **Brain.**—The brain, the agency of thought and volition, exercises upon the origin of the nerves a certain power, which may be aptly enough illustrated by the power which a voltaic battery exerts upon a conducting wire; and by this action, some subtle influence is transmitted along the nervous cord to the muscle, where it terminates, or on the fibres of which, as explained above, it is looped; and this influence, acting in a specific manner, causes the contraction, which imparts motion to the member with which the muscle is connected.

It is impossible to read this simple statement without being struck with the analogy which prevails between the nervous system and a voltaic arrangement. If, as is contended, each nervous cord, upon arriving at the muscle upon which it acts, returns to the brain, nothing is wanting to complete the analogy to the electric telegraph. The brain is the telegraphic instrument receiving the dictates of the will. The nervous cord is the conducting wire which, arriving at the remote station—that is, the muscle—returns to the brain to complete the voltaic circuit. The message delivered to the muscle produces the commanded motion, just as the voltaic current imparts motion to the signal needle at the distant station.

That the nervous cord is in fact the conductor of the physical influence, whatever it may be, transmitted by the will from the brain, is proved by the fact that if the nerve be cut anywhere between the muscle and the brain, all power of the will over

the muscle ceases,and the member to which the muscle imparts motion becomes paralysed. It is not even necessary to cut the nerve to produce this effect. If the brain at the origin of the nerve be submitted to a certain compression, its power of transmitting the influence, whatever it may be, to the muscle, will be suspended, and will only be restored when the compression is removed.

32. Among the physical researches in which physiologists have been from time to time engaged, with a view to discover the nature of the influence which the will thus transmits from the brain to the muscles, those which have obtained by far the greatest celebrity—not so much for the physiological consequences, as for the vast and important discoveries which have resulted from them—are those of Galvani, Professor of Anatomy at Bologna, from whom the branch of physics called "galvanism" has taken its name.

It is found that the nervous cords, like metallic wires, are good conductors of electricity, and that if, after paralysing a member by cutting the nerve which connects its muscle with the brain, the extremity of the nerve leading to the muscle be put in connection with a voltaic battery, the muscle will be contracted and the member will be moved in the same manner as it would be by the action of the will. In like manner, if after death, when thought and will have ceased, the nerves which connect the brain with the several muscles which govern the members and the organs be put in connection with a voltaic battery, motions will be produced precisely the same as if thought and will had been restored to the subject. Galvani's original experiment upon the limbs of a frog is well known, and has been often repeated. Bailey substituted a grasshopper for a frog, and obtained similar results.

33. Like effects have been produced upon the human body recently deprived of life. Aldini in this way imparted violent action to the various members of a body; the legs and feet were moved violently, the eyes opened and closed, and the mouth, cheeks, and all the features of the face were agitated by distortions. Dr. Ure connected one of the poles of a battery with the supra-orbital nerve of a man cut down after hanging for an hour, and connected the other pole with the nerves of the heel. Each time the circuit was completed and broken, the limbs and features were moved with a fearful activity; rage, anguish, despair, and horrid smiles were successively

expressed by the countenance, with the most revolting resemblance to actual vitality.

34. **Nerves of Motion and Sensation.**—The nerves, however, have another function equal in physiological importance to that in virtue of which they impart motion to the organs and the members. They are the conductors by which impressions produced in all parts of the system, whether by external or internal causes, are transmitted to the brain, and by which the corresponding sensation is produced. When we behold a visible object, the impression produced upon the eye is transmitted by the optic nerve to the brain, and we obtain a perception of the object. When the vibrations of the air produced by a sounding body act upon the ear, or when the effluvia of a rose act upon the olfactory organ, the auditory or the olfactory nerve transmits the impression to the brain, and we are conscious of the sensation of the sound or of the odour. If we touch a body which is rough or smooth, sharp or blunt, hot or cold, the nerves which are near the point of contact will be affected in a peculiar manner by the texture, form, or temperature of the body, and will, as before, transmit to the brain corresponding impressions, which will produce the sensations by which we acquire the perception of the qualities of the body thus touched.

Thus it appears that the nerves include not only the mechanism of mobility, but that of sensibility ; and the researches of physiologists have conducted them to the very curious and interesting discovery, that the nerves which constitute the mechanism of sensibility are altogether distinct from those which constitute the mechanism of mobility. The latter have been accordingly called the nerves of *motion*, and the former the nerves of *sensation*.

Notwithstanding the complete independence of these two nervous systems, so far as relates to their respective functions, they are often united mechanically together, so that their fibres form a single nervous cord. In such cases, however, they frequently diverge one from another, like the branches of the letter Y, before arriving at the brain, so that one branch includes only the fibres of the nerve of motion, and the other only those of the nerve of sensation. If, in such cases, the latter branch be cut, the organ to which the nerve is appropriated loses its sensibility, but retains all its mobility. The will has still complete control over it, but the organ becomes insensible to external impressions.

If, on the contrary, the other branch be cut, the organ retains its sensibility, but becomes paralysed.

If, in fine, both branches be cut, the organ is paralysed, and also rendered insensible.

35. **Digestive Apparatus.**—The nutritive matter supplied by the lymphatics to the blood is eliminated from the food by an apparatus called the alimentary canal, consisting of the stomach, the intestines, the liver, pancreas, and other appendages.

From the mouth, a pipe called the œsophagus conducts the food to a bag called the stomach, deposited within the cavity of the abdomen, immediately below the heart and lungs. From this cavity a flexible pipe called the intestine, measuring many feet in length, proceeds, and being coiled up is packed into the lower part of the abdomen. Into this pipe the liver sends one communication, and the pancreas another. The food undergoes a succession of changes, the first of which is effected in the stomach; and in its course there are mixed with it certain juices from the liver, the pancreas, and the coats of the intestine. The nutritive principle is gradually eliminated from the food in its progress through the stomach and intestines; and this principle, by a species of capillary action called *exosmose*, penetrates the coats of the stomach and intestine, and is received into the countless minute ramifications of the lymphatic system with which they are surrounded. The white blood, or lymph as it is called, is thus supplied to these parts of the lymphatics, and transmitted thence, as already described, to the venous trunks.

36. Having thus briefly described the organisation of the body, we shall resume each of the principal subjects here indicated, explaining them with all the detail necessary to render their principles understood; after which the several organs of sense will be described.

CHAPTER II.

THE BONES AND LIGAMENTS.

37. THE framework by which the softer parts of the organisation are sustained, called the skeleton, consists, like the body, of three distinct parts—the head, the trunk, and the members.

Trunk.—The trunk is a bony cage consisting, in the human species, of a jointed vertical pillar, called the *vertebral column*, extending from the lower extremity of the back to the base of the neck, to which are attached, laterally, a series of hoops united to a shorter bone in front, also vertical, and occupying the middle of the breast, called the *breast-bone* or *sternum*. The hoops just mentioned, being, therefore, divided behind by the vertebral column, and in front by the sternum, are resolved into two series of semi-circular, or rather semi-elliptical, pieces ranged one above the other at nearly equal distances, and in nearly parallel positions. These semicircular hoops are called the *ribs*, and they form an oval cage, the lateral diameter of which is greater than the antero-posterior, or that which passes from the sternum to the vertebral column. Within this cage the heart and lungs are included and protected.

Upon the summit, or capital, of the vertebral column the head is mounted and supported. To the superior lateral corners of it are attached the superior or thoracic members, which, in man, are called the *arms;* and to the inferior lateral corners are, in like manner, attached the inferior or abdominal members called the *legs*.

38. **Number of the Bones.**—Without taking into account some small detached bones, regarded as accessory to particular organs rather than properly belonging to the general framework of the system, the skeleton may be said to consist of 198 separate bones, which are, nevertheless, connected together in the manner already described, by means of ligaments and other cartilaginous appendages. The distribution of these bones in the system is as follows :—

Vertebral column	26
Skull	8
Face	14
Hyoid-bone of the neck	1
Ribs and Sternum	25
Arms (32 each)	64
Legs (30 each)	60
	198

We have here used the terms "legs" and "arms" in the popular sense of the words, as including in the former all the bones of the legs and the feet, and in the latter all those of the arms and the hands.

39. **Growth of the Bones.**—The enumeration of the bones is not so obvious a problem as it might at first appear, inasmuch as the number of separate and independent bones is not the same at different ages. Thus, the bones are more numerous in infancy than in youth—in youth than in manhood—and in manhood than in old age. In the first stage of intra-uterine existence, the bones are composed exclusively, first of mucus, and later of cartilage. In successive stages of growth they receive accessions of other constituents, which give them that hardness that constitutes the osseous character. Ossification gradually spreads with time, and bones which in earlier stages were independent, or only connected together by cartilage, are united so as to form single osseous pieces by the ossification of the connecting cartilage. In enumerating the bones, therefore, it is necessary to specify the epoch of life to which the proposed enumeration is applied. That which is given above is accordingly applicable to the age of from twenty-five to thirty, when the development of the organisation may be considered as most complete.

40. **Constituents of the Bones.**—When it is considered that the purpose of the bones is to give solidity and strength to the frame—not merely for the support and motion of their own weight and that of the other parts of the body, but also to resist those external forces to which the body in the common incidents of life is exposed, and which would tend more or less to derange or fracture them,—it may be anticipated that in accordance with that spirit of unbounded wisdom and beneficence which is observable in all the works of Nature, and in none more so than in the animal organisation, the constitution

and structure of the bones should be such as would resist all these causes of ordinary disturbance. They must be firm to resist pressure, tough to resist extension, and more or less elastic to be capable of yielding to a limited extent without fracture. We find, accordingly, that their constituents are such as to confer on them precisely these three important qualities, and to impart them in that degree which is necessary and sufficient to protect them from all injury and derangement arising from disturbing causes of ordinary occurrence.

The bones derive these properties from three constituents—fibre, cartilage, and certain species of earthy matter, the principal of which is phosphate of lime. From the fibre they derive toughness ; from the cartilage, elasticity ; and from the earthy matter, hardness and firmness.

41. In comparing one with another the different species of animals, these constituents are found to enter into the composition of their bones in different proportions, each constituent predominating according as one or other of the mechanical qualities they confer are most necessary to the habits and economy of the animal. Thus, in the case of fishes which inhabit an element that supports their weight, the bones having no need of the strength of pillars, but, on the contrary, requiring great elasticity to give effect to the muscular action of the animal in propelling itself through the water, are formed with a very large proportion of the cartilaginous constituent, and in certain species are so nearly destitute of the calcareous element, that they have received the name of *cartilaginous fishes*.

On comparing one with another the different species of land animals, the same beneficent adaptation is everywhere observable. Those animals whose habits and economy require most elasticity in their solid structure, have a greater proportion of cartilage ; those which require most toughness have bones with a predominance of fibre ; and those which require greatest solidity and firmness have a larger proportion of the calcareous constituent.

42. Not only is the nice adaptation of the proportion of the constituents of the bones to the necessities of animal life observable in species compared with species, but it is even found to prevail in the same animal compared with itself at different ages, and in different parts of the organisation at any given age.

The helpless infant, exposed by a thousand incidents to external shocks, has a skeleton, a considerable part of which, being

gristly and cartilaginous, is yielding and elastic, and therefore incurs little danger of injury. The youth, whose augmented weight and increased activity demand greater strength, has a larger proportion of the calcareous and fibrous elements, but still sufficient of the cartilaginous to give the necessary combination of firmness, toughness, and elasticity. As age advances, and prudence and tranquil habits increase, as well as the weight which the skeleton has to sustain, the calcareous element increases and the cartilaginous diminishes.

43. In comparing bone with bone at any given age, the same beautiful adaptation is observable, each having just that proportion of earth, cartilage, and fibre which is best suited to its functions. Thus, for example, the temporal bone, in which the organ of hearing is mounted, is as dense and hard as marble, whence it has been called the *os petrosum*. It is therefore eminently suited, by its vibratory character, to propagate to the auditory nerves the undulations of the air.

The bones of the heel and elbow, on the other hand, which are subject to the constant action of powerful muscles—which, in the case of the heel, have to react upon the entire weight of the body—require all the toughness of a rope, and are accordingly found to contain a predominance of the fibrous element. In fine, the columnar bones of the leg, which form pillars upon which the weight of the body is sustained, require and possess a corresponding excess of the earthy element.*

44. That the bones do actually consist of such a combination of earthy and gristly matter as has been described above, can be ascertained by two simple and easily executed experiments, the result of one of which is the exhibition of the gristly matter separate from the earthy; and of the other, the exhibition of the earthy separate from the gristly.

If a bone be steeped in dilute nitric or hydrochloric acid, the earthy constituent being dissolved by the acid will be extricated; the tough, flexible, and gristly substance, which will not be affected by the acid, remaining.

If, on the other hand, the bone be burnt in an open fire, with free access of air, the fibrous and gristly part will be first charred, and afterwards will undergo the process of combustion. The earthy matter alone will remain, having a white, brittle consistency, still preserving its original shape, the bone having, however, lost about a third of its weight. On examining this earthy residuum, it is found to consist principally of a chemical substance called phosphate of lime, —being, as the name indicates, a salt compounded of phosphoric acid

* Bell on the Hand, 6th Edition, p. 301.

and lime. Other earthy substances are combined with it, but in smaller proportions.

The exact analysis of bone, according to Berzelius, whose results were confirmed by the experiments of Mr. Middleton, made in the laboratory of University College, London, is as follows :

	Berzelius.		Middleton.
Animal matter	33·30	—	33·43
Phosphate of lime	51·04	—	51·11
Carbonate of lime	11·30	—	10·31
Fluoride of calcium	2·00	—	1·99
Magnesia, wholly or partially in the state of phosphate	1·16	—	1·67
Soda, and chloride of sodium	1·20	—	1·68
	100·00		100·19

These proportions, however, as has been already stated, are subject to some variation.

45. In the preceding paragraphs the variation of the constituents of the bones at different ages has been assumed, as it has been generally admitted hitherto by anatomists. Some recent experiments by M. Nélaton have called in doubt these facts. That anatomist maintains that he has found the proportion which prevails between the organic and calcareous elements of the bones to be the same at all periods of life, and that the bony tissue is not a mere mechanical mixture of gelatine with the calcareous constituent, but that it is a chemical combination, into which these elements enter in definite proportions. The experiments of M. Nélaton were repeated in concert with M. Sappey, when the same results were obtained ; the average proportion of the organic to the inorganic elements at all periods of life, from the moment of birth to the most advanced old age, being found to be that of 32 to 68.

These results, nevertheless, do not affect the moral argument, based upon the varying mechanical qualities of the bones at different periods of life, adapting themselves to the varying circumstances in which the individual is placed. The fact that these qualities of the bones do so vary, is not disputed by Messrs. Nélaton and Sappey, who only deny that this variation can be explained by any change in the proportion of the constituents. They admit the gradually increasing density, decreasing vitality, and increasing rigidity of the bony tissue with increasing age, but propose other hypotheses for its explanation.

46. The mechanical properties of the bones depend upon their structure and their form, as well as on their constituents. The same adaptation to their functions will accordingly be found as well in the former as in the latter.

On sawing through a bone at right angles to its surface, so as to exhibit by section its internal structure, it will be found to consist externally of parts which are dense and close in texture, having a resemblance to ivory ; and internally, of parts whose texture is open, reticular, and cellular. Anatomists have accordingly denominated the former the *compact* ;

and the latter, the *cancellated* tissue, from the Latin word "cancelli," signifying lattice-work.

Such a combination of dense exterior texture and light porous interior structure is precisely that which, according to mechanical principles, must produce the greatest amount of strength combined with the least amount of weight.

47. **The form of the bones** is infinitely various; and whatever classification of them may be attempted, must be more or less arbitrary and vague. That which has been generally received and found practically convenient, though subject to some objections, resolves the parts of the skeleton into:

1°. *Long bones*, which are those of which the thickness or diameter bears a small proportion to the length; the principal bones of the legs and arms are examples of these.

2°. *Short bones*, which are those whose thickness or diameter does not differ much from their length; the small bones of the wrist and ankle are examples of these.

3°. *Tabular bones*, or, as they are sometimes though improperly called, flat bones, are those of which the thickness bears a very small proportion to the length and breadth. The surfaces of these are generally more or less curved; one being convex, and the other concave. The bones which form the roof and sides of the skull are examples of these.

4°. *Irregularly formed bones*, not very properly so denominated, are such as cannot be brought within any of the preceding classes. Such bones generally occupy the middle part of the body, so as to be intersected by the median plane, which in general divides them symmetrically. The vertebræ, and certain internal bones of the head, present examples of this class.

48. **The median plane** here referred to is an imaginary plane passing through the centre of the body in a vertical direction, from the middle of the front to the middle of the back, dividing the body into two parts, the right and the left, perfectly similar and symmetrical. This plane is of great use in defining the position of different organs of the body, and will be frequently referred to for that purpose.

49. **The long bones,** owing to the length of the lever upon which any strain upon them must act, require to be constructed upon those principles which will confer upon them the greatest amount of strength which a given weight of material can receive. According to the principles of mechanics, their forms should be that of a hollow tube; such is accordingly found to be the case: and moreover, the mechanical principle is carried

to its extreme limit, inasmuch as the material of the tube gradually increases in density in proceeding outwards from the internal to the external surface, the internal parts being composed of cancellated, and the external of compact tissue. The transition from the one tissue to the other is not sudden and definite, but gradual and imperceptible, no distinct limit being discoverable fixing the point at which the cancellated tissue ends and the compact tissue begins.

The difference between these bony tissues is one, therefore, of degree, and not of kind. They are both porous, but porous in very different degrees; the porosity of one being visible to the naked eye, while that of the other is microscopic.

50. **Short Bones.**—The strains to which these are subject are considerably less, and act upon them with a much less leverage; there is, therefore, less necessity for pushing the mechanical principle which confers strength upon them to its extreme limit; and it is accordingly found that their internal texture is everywhere spongy, the compact tissue being limited to a thin superficial crust which invests them.

51. **Tabular bones** are composed of two nearly parallel shells of compact tissue, the intermediate space being filled by cancellated tissue, called diploe. This combination, besides the general purpose of augmenting the strength conferred upon a given quantity of the material, is attended with the further advantage of intercepting in a greater or less degree the vibrations produced by shocks and concussions proceeding from external causes, and thus acting as a sort of damper or buffer for the preservation of the body. This advantage deserves a special notice in the case of the skull, which, as has been already explained, includes within it the important and delicate organisation which constitutes the centre of thought, sensation, and voluntary motion. A concussion upon the bony casing surrounding this, would, if not intercepted, derange or even paralyse the most important of the vital functions. The spongy tissue, therefore, interposed between the inner and outer shells of the compact tissue, is here of capital advantage; it has the same effect precisely as has the padding which lines the warrior's helmet or the huntsman's cap; it intercepts the force, and arrests the vibration of the blow.

52. **The Hair.**—Though not immediately connected with the subject of the bones, it may not be out of place here to

remark one of the advantages which the hair covering the surface of the head supplies. As the intermediate spongy tissue in a certain degree intercepts a concussion received by the external tissue of the bone, the hair in like manner protects that tissue itself, receiving and intercepting every external force ; and it may be added, that when in its natural state its growth is allowed, it falls upon the neck, and protects the upper vertebræ as well as the skull. It has been well observed that art, even in the rudest stages of society, takes nature for her model ; and we find the helmet of the ancient warrior crested with horsehair, descending to a certain point over the neck and shoulders, to give that protection to them, which the natural hair is intended to afford to the naked savage ; and this expedient of ancient times continues to prevail in the modern military costume.

53. The distribution and arrangement of the compact and spongy tissues in the irregular bones, is determined on like principles.

That these two tissues differ in nothing save the degree of their porosity can be shown by slicing a bone at right angles to its length. The reticulated structure of the cancellated tissue will then be evident to the naked eye. On approaching the compact tissue, the pores and cells become gradually smaller, until they become altogether imperceptible. If the section, however, be submitted to examination with the microscope, it will present the appearance of a surface covered with numerous little round apertures, as shown in fig. 3, which are the sections of a multitude of small canals which traverse the bone longitudinally, and are called *Haversian* canals, from Havers, an eminent English anatomist, who first directed attention to them. These canals, which in the living bone give passage to a multitude of blood-vessels and nerves, vary from the two-hundredth to the two-thousandth of an inch in diameter.

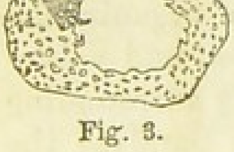


Fig. 3.

54. In fig. 3 the section of the bone, which is the ulna deprived of its earthy constituent, is shown in its natural size. The small portion of it which in that figure is marked with dark shading, is shown in fig. 4, as it appears with a linear magnifying power of twenty ; the Haversian canals now appearing as circular or oval openings, each surrounded by a series of concentric lamellæ or fine plates ; other lamellæ, especially near the borders, being parallel to the surface of the bone. This section has been taken, by permission, from Dr. Sharpey's General Anatomy. A similar section, somewhat different in its details, given me by Dr. Mandl, is shown in fig. 5.

In fig. 4 it will be observed that a multitude of small dark specks are

Fig. 4.

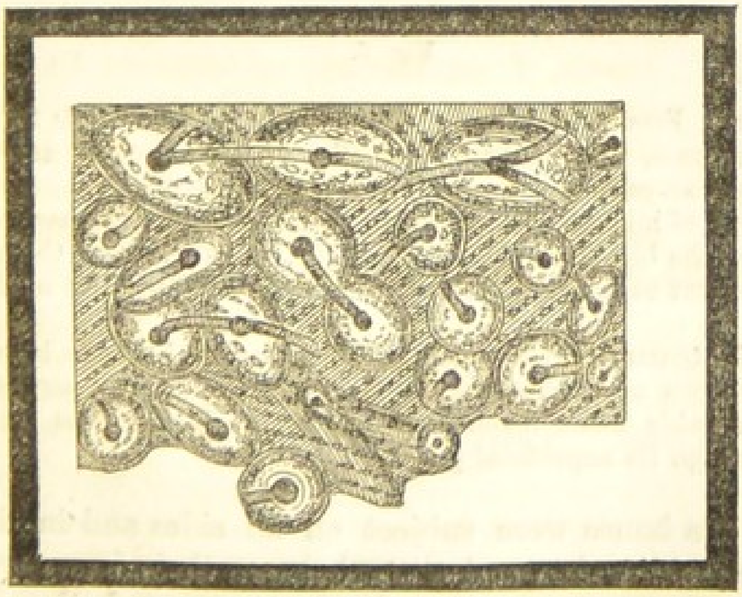


Fig. 5.

seen interspersed among the lamellæ which surround the Haversian canals. These were long supposed to be elementary particles of bone, and were accordingly called *osseous corpuscles.* The improvement of the microscope, however, led to the discovery of their true character. When viewed with a linear magnifying power of about 200, they are distinctly seen to be holes like the Haversian canal itself, but smaller and of a different form. A transverse section of the compact tissue of one of the bones of the arm, as viewed with a linear power of 150, is shown in fig. 6. What were formerly corpuscles, now called *lacunæ*, here appear to form part of the concentric lamellæ, having a form which has been compared to that of little

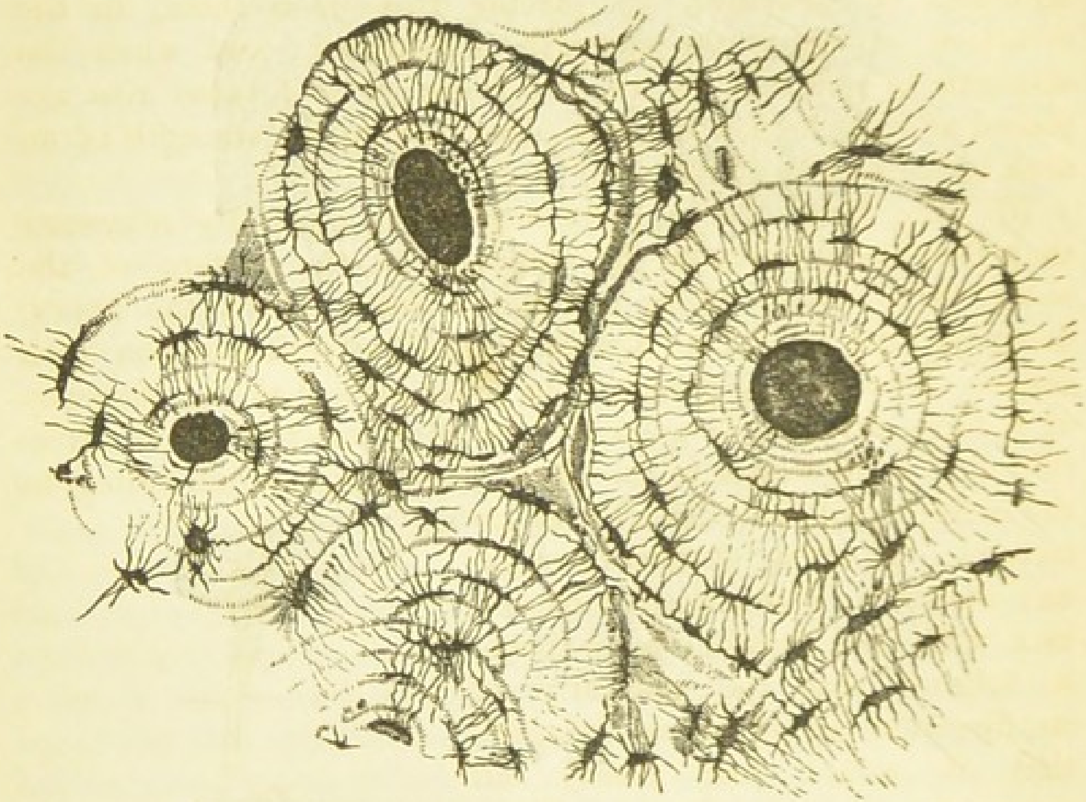


Fig. 6.

black insects. From the lamellæ, innumerable minute canals traverse the intermediate space, connecting the lamellæ with each other and with the central Haversian canal.

This system of microscopic canaliculi obviously serves as passages for the circulation of the blood, and thereby for the distribution of the necessary nutritive element to produce the growth and repair the waste of the bone.

55. **Periosteum.**—This vascular apparatus of the bone is completed superficially by a membrane which covers it, called the *periosteum*, in which innumerable blood-vessels and nerves ramify and pass thence into the bone through its superficial pores.

56. If the bones were subject on all sides and in all directions to equal strains and disturbances, their forms would be generally cylindrical or otherwise uniform, and the compact

tissue would have uniform arrangement and thickness. This, however, is obviously not the case in nature. Different bones, and different parts of the same bone, are subject to different external strains and disturbing forces ; and the form of its section and relative thickness, and arrangement of the compact tissue, will vary accordingly. It will be thickest on that side, and in that part, which is most exposed to strain and disturbance. In the case of the tabular bones, the necessary resisting force in particular directions is obtained without sacrificing lightness of structure, by placing ribs upon them, in the direction in which the strength is required ; and when the strength is required in all directions, two of these ribs are placed at right angles to each other, giving the strength of an arch in transverse directions.

57. The form of the body renders it generally necessary that the muscles should be disposed on the surface of the bones, their fibres, whose contractile force moves the bones, being parallel to and in almost immediate juxtaposition with them. Now it is a principle in Mechanics that the efficiency of a force which acts upon a lever is greatest when its direction is at right angles to the lever, and decreases indefinitely as the obliquity of that direction is increased. If, then, between its origin and insertion, a muscle lies in contact with and parallel to a bone, it follows that the obliquity of its direction would be so extreme, that it would lose nearly all power to move the bone. Thus, if the joint on which the bone turns be at J, fig. 7, the muscle M lying in juxtaposition with the bones and parallel to them, would exert very little power upon its point of insertion, I ; while if it had the position represented at M′, fig. 8, it would then act at right angles to the bone upon the point I, and therefore with complete efficiency. But since such a position of the muscle is not compatible with other conditions of the economy, the inconvenience is removed by another expedient. The bones are usually enlarged in a considerable proportion at the joint ; a circumstance rendered necessary by other

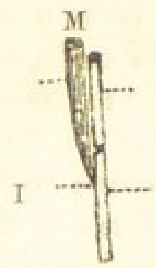


Fig. 7.

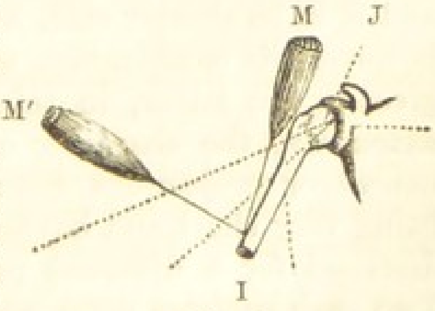


Fig. 8.

mechanical considerations. This enlargement forms what is called the head of the bone; and as it always lies between the origin of the muscle and its insertion, the muscle must necessarily pass over it.

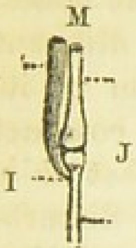


Fig. 9.

58. The effect of this, as will be evident from fig. 9, is to render the direction of the force of the muscle much less oblique, and consequently to give it greater power over the bone. If the enlargement at the head of the bone be considerable, and the point of insertion be placed near to it, the action of the muscle will be nearly perpendicular to the bone.

59. The points of insertion of the muscles which move the long bones, are generally at a distance from the joint which bears a small proportion to the entire length of the bone, and consequently the lever has the character of a lever of the third kind, where the power acts to mechanical disadvantage. But in these cases rapidity and promptitude of motion are of incomparably greater importance than the exertion of great force; and in proportion as the leverage afforded by the point of insertion of the muscle is small, the range of motion imparted to the bone by a given contraction of the muscle is increased.

60. In certain cases the leverage of the muscle is augmented in a greater or in a less degree by providing for its point of insertion, the extremity of a projection issuing from the bone at right angles to its surface, or nearly so; such a projection is called a *process* or *tubercle*, and is variously denominated according to its form or length. Thus, if its form be tapering and its length considerable, it is called a *spinous process*. If it have less length, or a blunt or round extremity, it is called a *tubercle*; and if it be shorter still, a *tuberosity*. Whatever be its form, however, its combination with the bone, from which it issues, gives to the latter, in relation to the muscle inserted upon its extremity, the character of a rectangular lever. These eminences or projections from the surface of a bone, sometimes being very short and having a flat circular or roundish end, are destined for a different purpose in the mechanical economy. Two such surfaces upon adjacent bones, corresponding in form and magnitude, being brought together, form a joint. In such cases, the process is usually called an *articular process*, but sometimes it is designated a *condyle*.

61. In the bones generally, and more especially in those that are tabular, there are numerous cavities, depressions, and perforations. The purpose of the perforations is to give passage to

nerves, veins, or arteries, from the parts at one side to those at the other side of the bone. Such perforations are called *foramina*, the most remarkable of which is that which is provided in the base of the skull for the passage of the medulla oblongata to the spinal cord, and which, as has already been stated, is called the *foramen magnum*. The base of the skull, however, is perforated with a great number of much smaller foramina, which give passage to the cranial nerves, and the vessels which maintain circulation in the brain.

Depressions and cavities, varying extremely in form, magnitude, and length, which prevail in the bones, are variously denominated *fissures*, *fossæ*, *grooves*, *furrows*, *notches*, and so on. When they are curved and shallow they are called *glenoid cavities*; but, when deeper, *cotyloid cavities*. The longitudinal depressions form usually the beds for nerves or blood-vessels; and the spherical or cylindrical cavities, the sockets for joints.

62. **Articulations.**—The expedients by which the bony pieces of the skeleton are connected together are called, as already mentioned, articulations, and are reduced according to the limits they impose upon the mobility of the parts connected, to three classes; 1st, Those which allow of no mobility, and are immovable joints. This articulation is called *synarthrosis*, from two Greek words—συν, *sun*, together, and αρθρον, *arthron*, a joint. 2nd. Those which are movable, allowing a certain limited play to the parts connected. This articulation is called *diarthrosis*, from the Greek word—δια, *dia*, through. 3rd. Those which are nearly but not altogether immovable, affording no more play than such as may be allowed by the elasticity of their cartilaginous connection; this articulation is called *amphiarthrosis*, from the Greek word—αμφι, *amphi*, both, as partaking, in some degree, of the character of both the former.

63. Examples of immovable joints will be found in the principal bones of which the skull is formed; those of movable joints, in the case of the bones of all the members, and of the intermediate class in the bones of the vertebral column.

The distinction between the mechanical functions of the extremities of a muscle, designated as its origin and insertion, has been already noticed. These two points generally lie on the two bones jointed together at different sides of their articulation, the insertion being placed upon the bone to which the muscle is chiefly intended to impart motion; and as the production of

motion usually proceeds from the central towards the extreme parts, the muscles generally have their origin in the bones which are nearer to the trunk, and their insertion in those more remote from it. Thus, for example, the muscles which move the fingers occupy chiefly the palm of the hand, and the fore-arm; those which move the fore-arm have their origin between the elbow and shoulder; and those which move the upper bone of the arm have their origin on the shoulder and breast.

Although the motion is thus usually imparted from the more central to the more extreme parts, the reverse takes place in certain exceptional cases, as for example, when the body is suspended by the hand, and elevated by the contraction of the brachial muscle. In that case, fig. 10, the insertions of these muscles in the fore-arm, and arm, become the fixed points; the action of the contractile power being thrown upon the points in the arm and breast, which are usually denominated their origin. In like manner, when a gymnastic exhibitor suspends himself by the feet with the body downwards, and raises himself by the muscular force of the leg, the usual mechanical functions of the origin and insertion of the *crural* and *femoral* muscles are interchanged.

Fig. 10.
THE CHIMPANZEE.

Having noticed thus generally the mechanical provisions of the bones, we shall pass to a brief examination of the arrangement, connection, and chief mechanical properties of the principal divisions of the body; the head, the trunk, and the members; which are represented collectively in fig. 11, where the names of the principal bones are indicated.

64. **The skull** is a hollow shell of bone, of an oval spheroidal form, wider behind than before, occupying the upper and

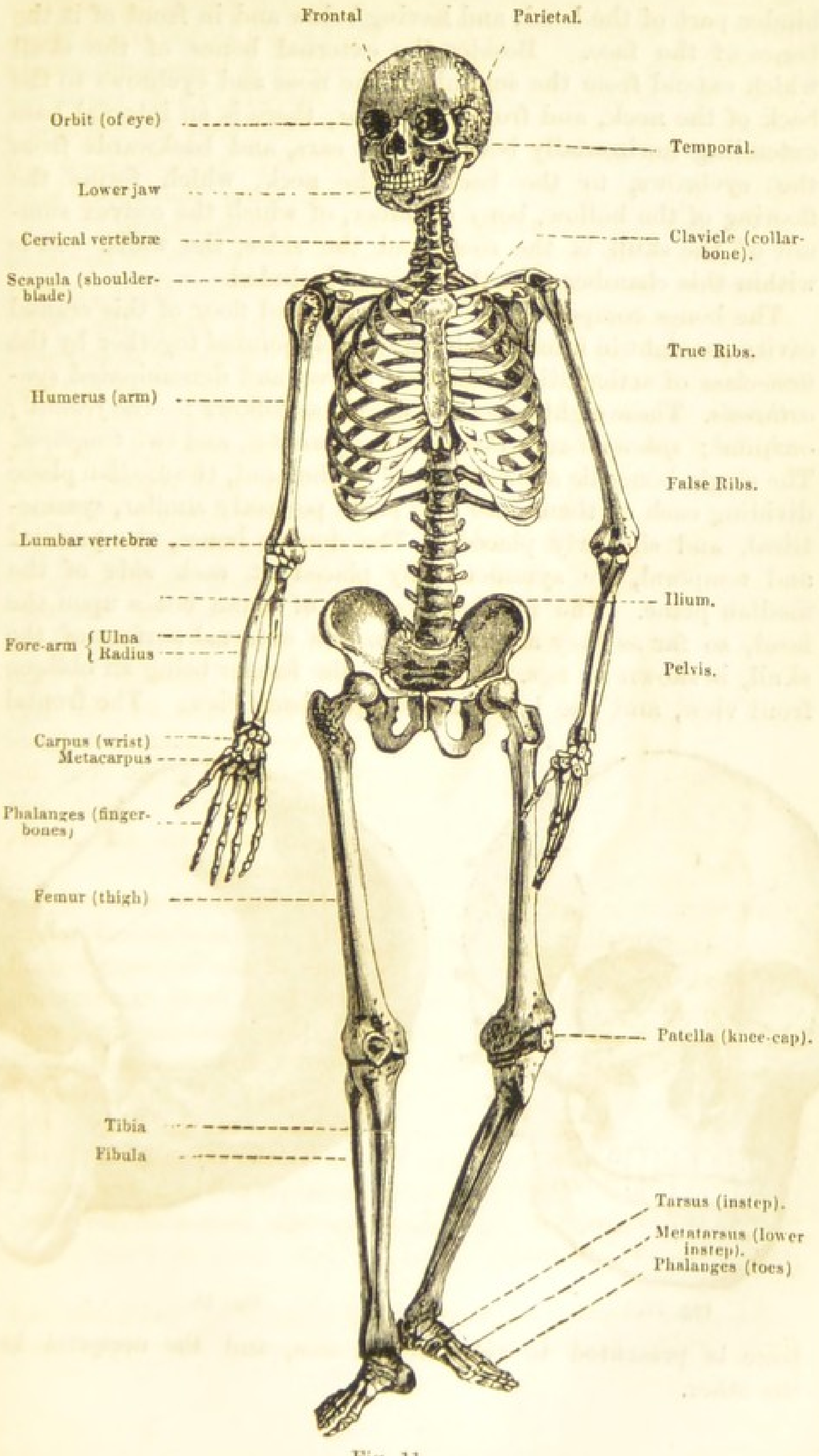


Fig. 11.
HUMAN SKELETON.

hinder part of the head, and having below and in front of it the bones of the face. Besides the external bones of the skull which extend from the summit of the nose and eyebrows to the back of the neck, and from ear to ear, there is an internal base extending horizontally between the ears, and backwards from the eyebrows, to the back of the neck, which forms the flooring of the hollow, bony chamber, of which the convex summit of the skull is the roof, and the sides, the walls. It is within this chamber that the brain is included.

The bones composing the roof, sides, and floor of this cranial cavity are eight in number, all immovably jointed together by the first-class of articulation described above, and denominated *synarthrosis.* These eight bones are named as follows :—the *frontal; occipital; sphenoid* and *ethmoid ;* two *parietal*, and two *temporal.* The single bones lie across the axis of the head, the median plane dividing each of them into two parts perfectly similar, symmetrical, and similarly placed. The double bones, the parietal and temporal, are symmetrically placed at each side of the median plane. The relative position of these bones upon the head, so far as they are visible on the external surface of the skull, is shown in figs. 12 and 13, the former being an oblique front view, and the latter an oblique back view. The frontal

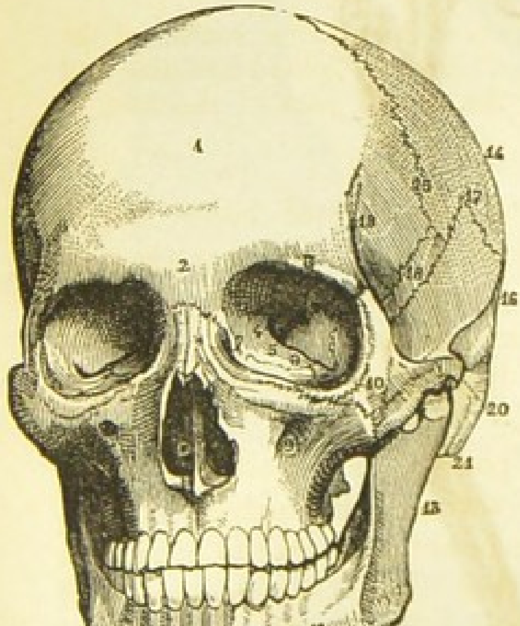


Fig. 12.

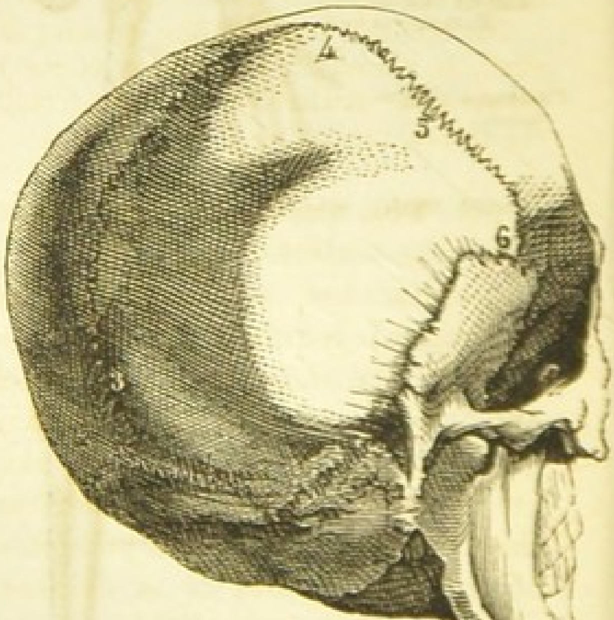


Fig. 13.

bone is presented to view in the one, and the occipital in the other.

The frontal bone occupies the forehead and part of the temples, and extends from the eyebrows and summit of the nose to the highest point of the skull ; it is convex externally, and concave internally, and is marked 1 in fig. 12 ; its lateral limit being marked at 15, and its limit on the temple at 18.

The left parietal bone is shown at fig. 12, [14].* The occipital bone, so far as it is visible on the external surface, appears at 13,[1] ; this part extends across the back of the skull, being articulated with the posterior edges of the two parietal bones. At the base of the skull the occipital is bent towards the neck in the horizontal direction, and forms that part of the base of the skull resting on the summit of the vertebral column, and consequently containing the foramen magnum already described.

The frontal and occipital bones are placed symmetrically with relation to the median plane which divides them, so that equal and similar parts lie to the right and left of it.

The only part of the sphenoid bone which is superficially visible is shown at fig. 12, [18] ; a similar portion being similarly placed on the other side of the skull.

The parts of this bone which are superficially visible over each ear are connected together by a continuous mass of bone which extends entirely across the skull, passing over the mouth and behind the nose, and forming, therefore, part of the base of the cerebral cavity.

The visible parts of this bone, forming part of the surface of the skull, are called its wings.

The temporal bones (fig. 12, [16]) are similarly placed over each ear, but, as in the case of the sphenoid, the portion externally visible is only a small part of them. At its lower part, the bone turns inwards, the deflected part being inserted in, and wedged among, the other bones, which form the base of the skull.

The ethmoid bone, in fine, forming no part of the external surface of the skull, is placed in the centre of its base, directly behind the nose and between the cavities of the eyes, forming the central part of the floor of the cranial cavity.

65. **The Sutures.**—The edges of the several bones which form the exterior shell of the skull are jointed together in a peculiar and admirable manner, so as to possess all the mechanical requisites to give security from external disturbance to the delicate organ which it is their especial purpose and function to protect and defend.

The edges by which the frontal, parietal, and occipital bones are connected with each other are serrated in such a manner that the projecting parts of each are inserted in the indentations of the other ; but it is evident that this, though it would prevent either from slipping under the other, by the action of a force pressing them edge to edge, would not prevent their

* It will be convenient to refer in this manner to the parts of figures, as they are indicated by numbers or letters. Thus, 12, [14] means the part of fig. 12 at which the number 14 is placed. In the same manner 40*a* would mean the part of fig. 40 at which the letter *a* is placed.

separation by one which would tend to draw them asunder. Their indentations, therefore, instead of being formed with edges converging outwards like the teeth of a saw, have the contrary form, the edges converging inwards, so that the projecting pieces of the two edges are engaged in one another, like those of two boards which in cabinet-making are "dovetailed" together. Such a mode of connection secures the bones as well from being drawn asunder as from slipping one under the other.

The solidity of their connection is further secured by another admirable arrangement. Towards the temples this dentelated and dovetailed connection is discontinued; the edges of the parietal overlying those of the frontal towards the temples, and the edges of the temporal bones overlying those of the parietal. The contiguous surfaces of the frontal and parietal bones at the upper part, besides being dovetailed, are so arranged that the edges of the frontal overlie those of the parietal. By this arrangement every possible external disturbance is resisted; the dovetailing resists forces which tend to move the edges of the bones towards or from each other; while the underlying parietal edge at the summit protects the frontal from being forced inwards, and the underlying frontal and parietal towards the temple gives equal protection to the parietal and temporal respectively.

The upper edges of the two parietals which pass along the crest of the skull from the frontal to the occipital are connected together in the same manner by the dovetailing of their dentelated edges.

The articulations of tabular bones edge to edge in this manner are called *sutures*. When they are dentelated and dovetailed in the manner described above, they are called *true sutures;* and when the edges overlap each other they are called *squamous sutures*, as resembling the scales of fishes.

The occipital is connected with the parietal and temporal bones by true sutures, while the temporal and sphenoid bones, overlapping at their edges the parietal and frontal, are connected with them by squamous sutures.

66. Now the least reflection upon the form and disposition of the cranial bones, as already described, will render manifest the great mechanical advantages which result from these latter modes of connection. The wings of the sphenoid overlapping at their edges the several lateral plates of the skull, bind them together in the same manner exactly as the walls of a building

are held together by the tie-beams of the roof, which are extended transversely between them; for it will not be forgotten that these great wings of the sphenoid, while they overlap the other bones at their edges, are themselves immovably connected together by the bony arch which passes across the base of the skull, from ear to ear. Such an arrangement may also be compared in its mechanical effect to the iron rods which are sometimes carried transversely between the walls of a building, connecting together plates or bars on the outside of the walls into which they are screwed. The temporal bones, although they are not connected by an arch extending across the skull, like the sphenoid, fulfil, nevertheless, the same mechanical functions. At their squamous suture they overlie the parietal, and, as already described, turning inwards at their lower parts, they enter into the base of the skull, among the bones of which they are firmly wedged and dovetailed; they therefore hold together the lateral plates, which they overlie, quite as effectually as if they were connected together, like the sphenoid, by a continuous bony arch.

67. The two compact tissues which form the exterior and the interior surfaces of the bones of the skull differ in their constituents—the internal having a greater proportion of the calcareous element; and they have consequently a corresponding difference in their mechanical properties, the exterior being tough and less hard, and the interior hard, brittle, and vibratory. It has been observed by Sir Charles Bell, that, as a necessary consequence of this difference of structure, there is a difference of articulation in the two systems. The inner coating, called, from its brittleness and hardness, the *vitreous table* of the bone, is everywhere united edge to edge by simple apposition, neither true nor squamous sutures existing between them. Such modes of connection could only be applied to a material having toughness and a certain degree of softness. Thus, the carpenter and cabinet-maker connect their materials by dovetailing, or by tenon and mortise, which would be wholly inapplicable to the materials upon which the stone-cutter and glazier work. Such a connection made in marble or glass could not be permanent, since the brittleness of the material would soon cause the projections and dentelations upon which the security of the joint depends to be chipped off. So inevitable is this effect in such materials, that, even where no mechanical joint, properly so called, is established, precautions are taken against it. The edges of the cylindrical

blocks of marble which form a column in architecture are prevented from coming into contact, and from splitting or chipping off in consequence, by the interposition of thin plates of lead.

The purpose of the difference of structure between the external and internal tables of the skull bones is evident. The external tables, being tough and more or less yielding, are adapted to resist such forces as would tend to crack the bone; while the internal tables, being hard, but brittle, would resist a piercing or cutting instrument, although they might be fractured by a blow.

68. On viewing the interior or concave surface of the shells of bone, by the connection of which the vault of the skull is formed, expedients will be perceived for strengthening it so as to enable it to resist external disturbing forces, which bear a striking analogy to similar contrivances in architecture. Every one is familiar with the effect of groining. A groin is an expedient for strengthening a roof, by a projecting ridge formed by the intersection of two arches whose concavities are in different directions. On the interior of the skull we find one rib, or groin, extending along the middle of the head, from the frontal bone to the projecting part of the foramen magnum, and another which intersects this at right angles, passing across the occipital bone. The point of intersection of these two groins is the thickest and strongest part of the skull, and with reason, since it is most exposed, being the part which would strike the ground in falling backwards.

The base of the skull is strengthened upon the same principle. "It is," says Sir Charles Bell, "like a cylinder groin, where the rib of an arch does not terminate upon a buttress or pilaster, but is continued round in the completion of a circle." In fact, the skull may be considered analogous to those arches which, instead of being sustained by abutments, are supported on inverted arches built into their foundation. By such expedients, the base of the skull, which, so far as regards its material, compared with the roof, is thin and feeble, acquires, nevertheless, sufficient strength to resist the shocks and concussions which are incidental to its connection with the spinal column.

The various bones of the head which have been described above, as well as others which support the organs and soft parts of the face, are immovably articulated together, and in this respect they form an exception to the general structure of the skeleton; for, even after all the softer parts have been

removed by decomposition or otherwise, the bones of the skull continue for an indefinite time to hold firmly together. In disinterring skeletons, when graves are opened, while all other parts are dismembered, the skull retains its integrity. Indeed the dismemberment of this part of the body without fracturing its component bones, requires no small exertion of anatomical and mechanical skill.

69. **Facial Bones.**—The bones of the face, which, with the exception of that of the lower jaw, are immovably articulated with each other, and with those of the skull, present five cavities, leading by as many canals and foramina to the internal chamber of the skull. In these cavities are lodged the most important of the organs, the two uppermost containing those of vision, the nasal cavities the olfactory organs, and the buccal cavity, those of taste, mastication, and articulation, as well as a part of the apparatus of voice, respiration, and deglutition. Since, however, these organs will severally come under review in a subsequent part of this work, we shall dismiss them for the present.

70. **The lower jaw,** the only movable bone in the head, shown in fig. 14, has a horse-shoe shape, the convexity being turned towards the front of the mouth.

At the inner extremities towards the ears the bone is turned upwards (fig. 14, [7]), forming two parts called *rami*, or branches, at an obtuse angle with the general direction of the horse-shoe. The upper edges of these branches are formed into concave cavities, technically called the *sigmoid notches*, from some resemblance of their outline to one of the forms of the Greek capital letter *sigma* (Σ or C). The posterior horn of this notch (14, [13]) is a hemispherical protuberance called the *condyle* (fig. 14, [12]), which forms the joint upon which the jaw moves. There are various grooves, foramina, and processes indicated in the figure for the attachment of muscles and the passage of nerves and blood-vessels, which need not be more particularly noticed here.

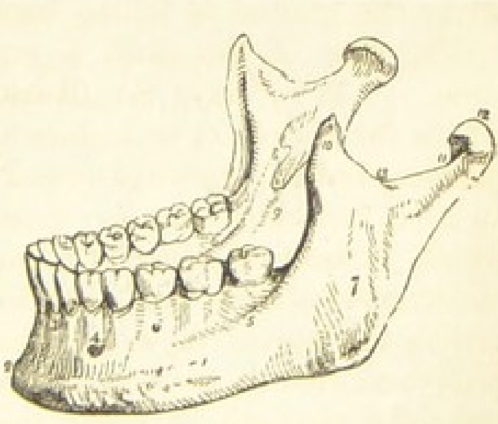


Fig. 14.

71. **Teeth.**—At the moment of birth, twenty teeth already formed and ossified are deposited, ten in the lower and ten in the

upper jaw, but are completely covered by the gums. The mouth is thus constituted exclusively for application to the mother's breast and for the suction of milk from it, and the stomach and intestines are organised in accordance with this for the due digestion of that aliment. The constituents of the healthy milk of woman are the same as those of the body of the child, and enter into its composition in a corresponding proportion. By the process of digestion, they are distributed among the several organs of the child's body, each passing to that for whose sustenance and growth it is fitted. At the age of from six to ten months, the first teeth penetrate through the gum, and towards the end of the second year the entire number have appeared. These twenty teeth are classified according to their peculiar forms, as incisors, canines, and molars. The incisors are chiselled, the canines pointed, and the molars present a broad and rough summit. When the mouth is closed the molars of the upper jaw, corresponding in position with those of the lower, rest upon them ; but the lower incisors and canines lie within the edges of the upper ones. In each of the jaws, there is, however, space for sixteen teeth, and consequently three places at each side remain unoccupied.

The relative arrangement of this set of teeth is shown in fig. 15, where the incisors are indicated by I ; the canines by C, and the molars by M ; the unoccupied spaces being marked ″

The first teeth which break through the jaw, are the middle

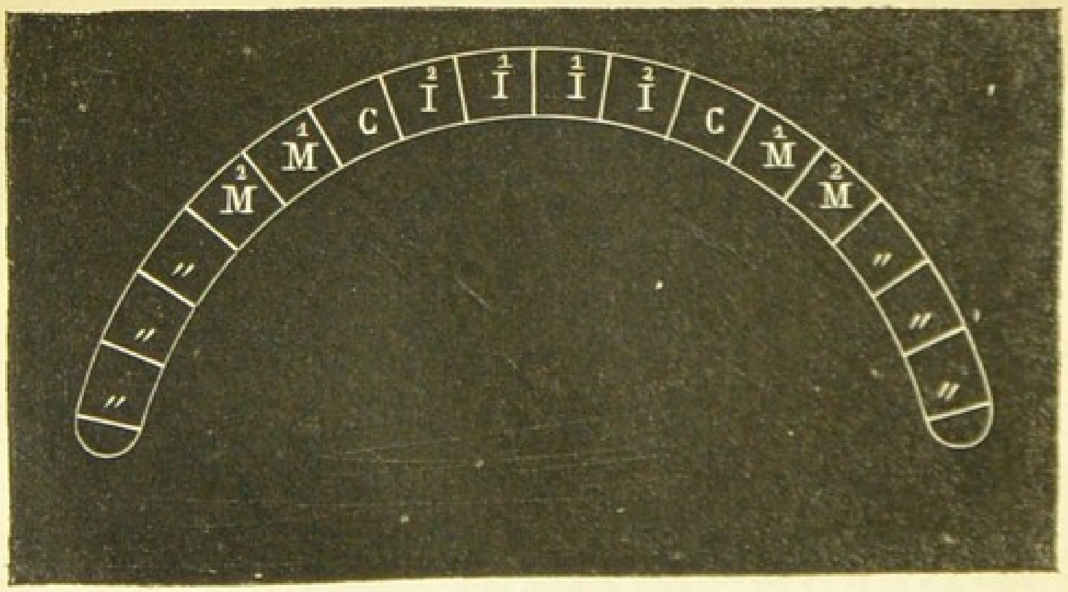


Fig. 15.

incisors I^1 I^1 ; these are succeeded in regular order by the lateral incisors I^2 I^2, the canines C C, and the molars M^1 M^1 and M^2 M^2.

These temporary teeth begin to be removed at about the age of five or six years, to make way for the permanent set.

The temporary molar teeth in each jaw are replaced by permanent teeth called bicuspids ; and four molars issue from the gum in each jaw, two at each side, occupying the first two of the three vacant places marked ″ in fig. 15, the first or anterior of these frequently appearing first of all the permanent teeth ; and at a more advanced age, two other molars fill the last vacant place in each jaw, marked ″ in fig. 15.

Thus, a set of sixteen permanent teeth is established in each jaw (fig. 16). The last four molars, which emerge at a period

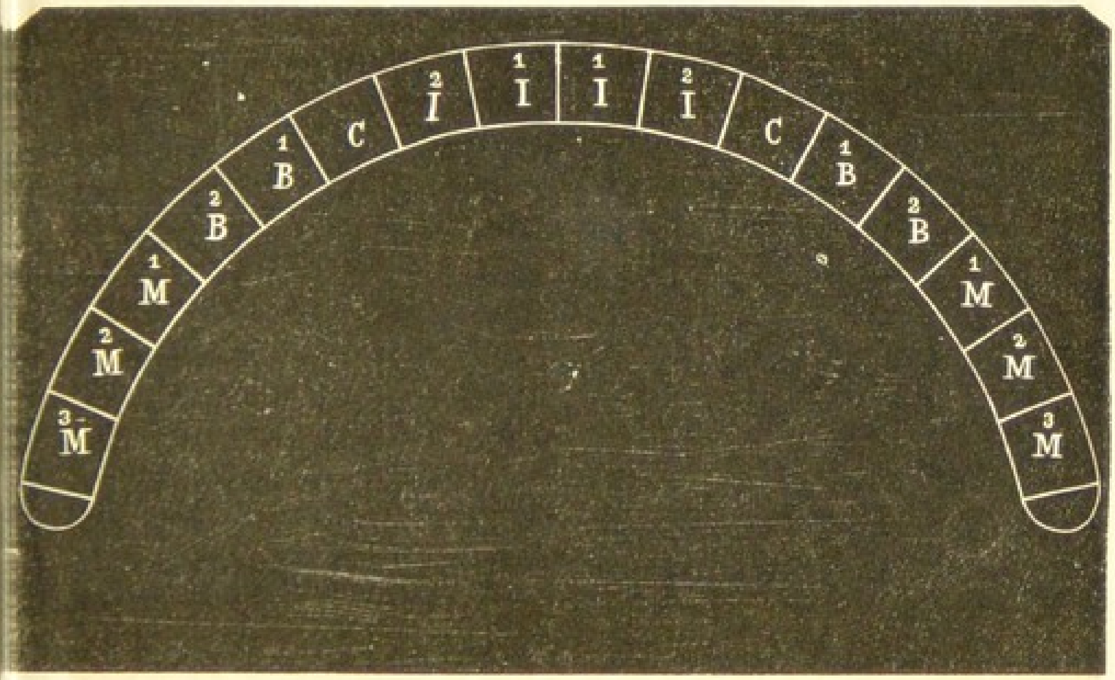


Fig. 16.

of life much later than the others, have been for that reason vulgarly called wisdom teeth.

The periods of the successive emergence of the permanent teeth are, according to Cartwright, as follows :—

Middle incisors of lower jaw (I,^{1}), and first molars (M,^{1})	5 to 7
Middle incisors of upper jaw	6 to 8
Lateral incisors (I,^{2})	7 to 9
First bicuspids (B,^{1})	8 to 10
Canines (C)	9 to 12
Second bicuspids (B,^{2})	10 to 12
Second molars (M,^{2})	12 to 14
Third molars (M,^{3}) (wisdom teeth)	17 to 25

The teeth, which vary in their forms as well as in their functions, are represented extracted from the jaw in fig. 17,

being numbered in their order, commencing from the median line backwards, and are denominated as follows :

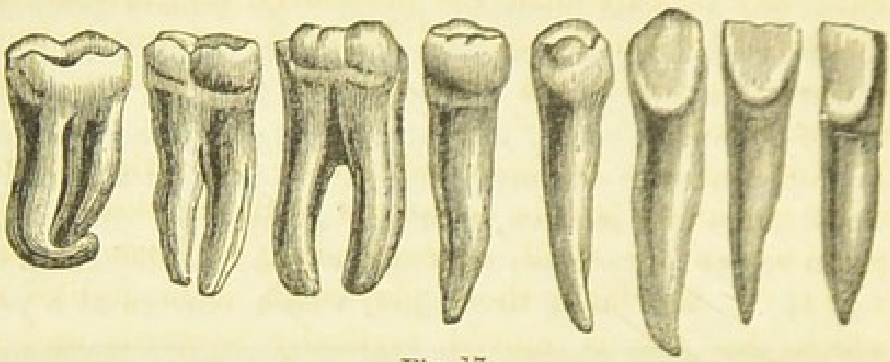


Fig. 17.

The function of the front teeth, as their name implies, is to cut or break the food into morsels of a magnitude suitable to the mouth ; and that of the posterior teeth to bruise and grind it, mixing it at the same time with the saliva secreted from glands under and around the tongue, by the action of which organ the pulpy food is thrown from side to side to be further ground and masticated.

In the upper jaw, which is fixed, there are implanted an equal number of teeth, similarly formed, and in corresponding positions, so that in jaws properly formed and jointed each molar tooth of the lower jaw, when the mouth is closed, comes directly under the corresponding tooth of the upper jaw. The same super-position of the incisors would not be convenient ; their sharp edges not affording a mutual bearing of sufficient breadth. In jaws properly formed, therefore, the edges of the lower incisors fall within those of the upper, the internal surface of the latter resting in contact with the external surface of the former. The very exceptional cases in which the lower incisors fall outside the upper must be considered a deformity giving a peculiarly disagreeable appearance to the face.

72. **Chin.**—It will be observed that the external surface of the horse-shoe below the incisors is inclined outwards at a slightly obtuse angle with the teeth. This form is an exclusive characteristic of the human species, and not found in any other class of animals. The maxillary bone in all other animals is inclined more or less backwards, the teeth being thus set in the projecting edge of the jaw.

The same peculiarity, though not so conspicuously apparent,

* The hooked fang of this tooth is an accidental malformation of not unfrequent occurrence.

is found in the upper jaw, which, from the teeth to the base of the nose, is vertical, while in inferior animals it is inclined backwards.

Hence may be explained the peculiarly disagreeable impression produced by that species of deformity presented in exceptional cases, in which the chin instead of inclining forwards retires backwards.

73. Nothing can be more admirable than the mechanism by which the under jaw is connected with the skull. Sockets are provided in the skull, corresponding in form to the condyles (14, [12]), in which these play with a hinge-like motion by which the jaw is moved vertically upwards and downwards, and the mouth opened and closed. But as the spherical form of the condyle gives to the joint, in a limited degree, the character of the ball and socket, the jaw has a certain small play laterally as well as forward and backward, by which the summits of the teeth of the lower can be rubbed in any direction against those of the upper jaw, so that the food between them can be treated exactly as grain is between two millstones. It is evident that for this purpose a horizontal play not exceeding the breadth of the teeth will be sufficient.

The connection of the lower jaw with the skull at the head of the condyle is shown in fig. 18, where it is inserted in a cavity corresponding with it in form, the cavity being lined with a cartilaginous cushion (18, [4]), which is therefore interposed between the bony surfaces, and being lubricated by synovia, secreted by an investing membrane, the jaw has the most perfect freedom of motion, and is exempt from all liability to jar, arising from the conflict of the bony surfaces.

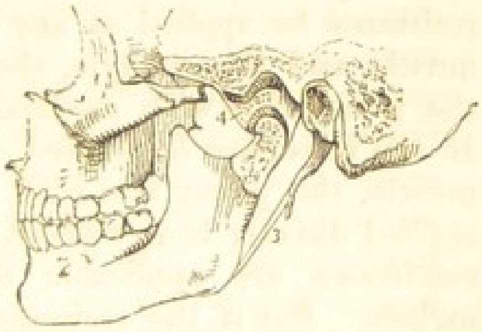


Fig. 18.

But if no expedient were provided to hold the jaw in the position here described, it would obviously fall out of its sockets by its weight. It requires, therefore, to be retained in its position, not only vertically, but laterally, so that it may not be liable to fall by its weight, or still more by the force of mastication, but may also be secured against derangement by lateral forces acting on it by the mutual pressure of the teeth in the latter process. These objects are attained by tying the

jaw to the skull by three ligamentous cords, one of which holds it up, and the other two bind it to the skull on the inside and outside, leaving it, however, sufficient play for the purposes of mastication and speech.

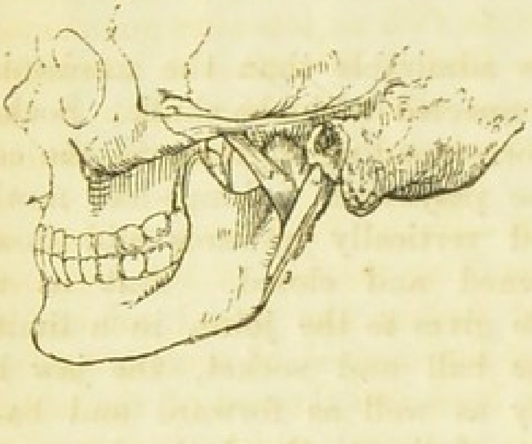


Fig. 19.

74. One of these cords (18, [2]), called the *stylo-maxillary ligament*, connects the lower angle of the horse-shoe with the part of the skull near the ear.

One of the other two cords, that which binds the jaw laterally and externally (19, [1]), is attached to the external edge of the branch of the jaw, and carried from thence to a point of the skull above the inner part of the upper jaw.

A similar cord is similarly applied on the inside of the bone.

75. The several muscles by which the jaw is moved being attached to points upon it at different distances between the condyle and the incisors, act upon the jaw as a lever, with a different degree of mechanical advantage, according to the part of the jaw at which the resistance is applied. Thus, if the resistance be applied at any point between the insertion of the muscle and the condyle, the lever is of the second kind, and the power acts with mechanical advantage on the resistance. If the resistance be applied directly over the insertion of the muscle, the power acts with its full effect upon it as if it were applied directly to it without the intervention of a lever. These conditions are applicable to mastication with the posterior molars. But if the resistance be applied at any point anterior to the insertion of the muscle, as will be the case if it be applied at the incisors, the canine or lesser molars, the contractile force of the muscles will act upon it with mechanical disadvantage, the lever being of the third kind, and the leverage of the resistance greater than that of the power; and this disadvantage will be so much the greater as the point of resistance is nearer to the first incisor.

Thus we see how admirable is the adaptation of the mechanism of the jaw to its appointed functions. The incisors, whose office is merely to cut, break, or tear the food into morsels small enough for the capacity of the mouth, act with

promptitude, and have large play but little mechanical force,—little being for such purposes needed. But when the morsels are transferred backwards to the molars to be ground to a pulp, and intimately mixed with saliva so as to be prepared for the chemical action of the stomach, they are brought to a part of the jaw where the force of the muscle is thrown upon them, first, with its full effect, and afterwards with an intensity augmented by increased leverage ; and the food is submitted to a bruising pressure and a grinding process which produce upon it the mechanical changes necessary to prepare it for healthy digestion.

76. **The Vertebral Column.**—If the head be a subject of great interest and importance as being the seat of the principal organs of sense, thought, and feeling, the spinal column is scarcely less so, as being at once the channel of communication of feeling and will between the head and the rest of the body, the pillar by which the head is sustained, and to the summit and base of which are appended the members of prehension and locomotion, and the shaft to which the whole framework of the trunk is attached.

Let us consider for a moment the complicated conditions which this columnar shaft is required to fulfil. *First*, it is a hollow tube, containing within it one of the most delicate and important organs of the body, the *spinal cord*, which must be protected, not only from all external disturbance, but also from all injurious strain or flexure : means of exit, meanwhile, must be given to the thirty-one pair of lateral nervous processes issuing from that cord. *Secondly*, planted in the pelvis, a concave mass of bone extending from hip to hip, in the same manner as the mast of a vessel is fixed in the keelson, it must have the strength and stability of a pillar to support upon its capital the head and the entire weight of the trunk and superior members attached to it from the neck to the lower extremity of the back. *Thirdly*, it must have flexibility and freedom of play sufficient to accommodate the necessary movements of the body and the head, and not more flexibility nor more play than is compatible with the due preservation of the spinal cord and of the nerves which diverge from it, and the blood-vessels which enter it and issue from it. *Fourthly*, it must have elasticity in the vertical direction sufficient to intercept all incidental shocks and concussions which take place at the lower part of the body, and to prevent them from arriving injuriously at the brain.

Now, if the problem to contrive such a column were proposed

to a human artificer, he would, without hesitation, pronounce that the conditions were reciprocally incompatible, and that the objects to be accomplished could only be attained imperfectly by a mutual compromise. Thus, the mechanical expedient, which would seem fitted to supply solidity to the column sufficient to support the weight of the trunk and the head, would be pronounced incompatible with any conceivable expedients which would give it flexibility in all directions, and still more so with any which would give it vertical elasticity. On the other hand, the due protection of an organ so delicate as the spinal cord, with upwards of sixty nervous ramifications equally delicate, for which orifices must be provided, to say nothing of blood-vessels still more numerous entering into and issuing from every part of the sides of such a tubular column, would seem even more incompatible with the quality of flexibility and vertical elasticity than solidity and stability itself ; and, viewing such complicated conditions, it would create no surprise that the most consummate mechanician should pronounce the construction of such a column impracticable.

Nevertheless, the problem has been perfectly solved, and all its apparently incompatible conditions completely fulfilled ; a circumstance which can create no surprise, however much the result may excite admiration, when it is remembered that the vertebral column is the work of One, before whose attributes difficulties cease to exist, and at whose word impracticabilities become realities.

77. This fine piece of mechanism then consists of a series of ring-shaped bones placed one over the other, like the stones of a column. But, since the annular surfaces would supply an insufficient extent of mutual bearing to give the required stability, a mass of bone of semicylindrical form is attached to the inside of each of these rings.

The form of this mass, which is called the *body* of the vertebra, may be conceived by imagining one of the cylindrical blocks which form a column to be divided by a vertical plane, passing through its axis or nearly so, the flat vertical surface produced by such a section being rendered slightly concave, so as to correspond with the form of the inner surface of the ring of which it forms a part. The upper and lower semicircular surfaces of such a block, being flat, will supply a sufficient basis of mutual support.

To obtain the first idea of the superstructure of the spine, we must therefore imagine a column built by placing one upon the

other a series of annular bones like that just described, each of which has attached to it a semicylindrical block of bone, the superior semicircular surface of which supports the inferior semicircular surface above it.

78. But such a column, though it might have solidity and stability, owing to the magnitude of the semicircular surfaces of the bodies of the vertebræ which rest one upon the other, and though it would present, by the exact correspondence and apposition of the openings of the rings, a tubular passage which would protect the spinal cord, would have no provision for the exit of the numerous nervous ramifications issuing from the one side and the other of that cord. This object would, nevertheless, be easily attained by forming on the edges of the bony rings at either side, notches in corresponding positions ; so that, when two such rings are superposed, the lateral notches in the upper edge of one coinciding with those in the lower edge of the other would, by their combination, produce a lateral orifice on each side, which would offer exits for the nerves and vessels passing from the spinal cord to the parts of the body, exterior to the vertebral column. Such lateral notches are accordingly provided in the edges of the rings, and the openings formed by their combination when the rings are superposed are called the *intervertebral foramina.* Each of the pairs of spinal nerves, formerly described, issue accordingly through these holes, and proceed thence to their several destinations.

79. Such arrangements would fulfil the conditions of the stability of the column, the protection of the spinal cord, and would supply suitable conduits for its ramifying nerves. But it would obviously be altogether destitute of flexibility and vertical elasticity. It could only be bent by separating, more or less, the contiguous surfaces of the vertebræ, and thus exposing the spinal cord. It would be so entirely destitute of vertical elasticity, that the momentum of any blow or concussion on the lower part of the body would be propagated with unmitigated force to the head ; so that, if a person leaping came with his feet to the ground, producing a momentum proportionate to the weight of the entire body multiplied by the velocity with which it would strike the ground, the head would suffer the concussion which would be produced by a fall on the head, instead of on the feet.

The expedients by which such an evil is prevented are as admirable as the other provisions in the mechanical structure of the body. The contiguous surfaces of the vertebræ are not

in immediate contact. Between the flat semicircular surfaces of their bodies, thick discs of cartilaginous substance are interposed, which are firmly adherent to the semicircular surfaces of the bones. These discs are highly elastic and resisting, and are also more or less flexible ; so that the surfaces which they connect are not only capable of moving through a certain limited space towards and from each other, maintaining their parallelism, but are also capable of being inclined to each other on any side, by the compression of the interposed disc of cartilage on one side and its extension on the other. Thus, by the same expedient, the column receives at once flexibility and vertical elasticity, without being in the least deprived of solidity and stability, inasmuch as the firm adherence of the interposed cartilaginous discs to the surfaces of the vertebræ effectually prevents all lateral displacement.

The same expedient secures the fulfilment of the other condition of the spinal problem ; since, by stopping up the interstices between the parallel vertebral surfaces, the spinal cord is as completely enclosed as if it were protected by a continuous tube of bone.

When it is considered that this column has to support the entire weight of the trunk, the head, and superior members, it will be easily conceived that, however tenacious these interposed cartilages may be, they cannot be regarded as altogether sufficient to resist the strains in all directions which so great a weight, liable in virtue of the flexibility of the supporting column constantly to shift its direction, would produce. Numerous other accessory expedients are accordingly provided, adapted by their structure and position to resist these various strains.

80. Along the front or convex side of the column, each vertebra is strapped to those which are above and below it by strong fibrous ligaments, which are inserted in the middle of the convex side of the body, and which are accordingly stretched tightly over the edges of the intervertebral fibro-cartilaginous discs. To afford further strength and security, another series of similar ligamentous straps are extended over these, connecting in pairs every third vertebræ ; and, to render assurance doubly sure, another series of similar straps stretched over these last connect the body of each vertebra with that of the fourth or fifth above or below it.

This series of fibrous straps, extending longitudinally over the entire length of the front of the column, is called by

anatomists the *anterior common ligament*, and its mechanical purpose is evidently to resist all backward strain of the column.

An expedient similar precisely to this is applied to the posterior surfaces of the bodies of the vertebræ, which form part of the interior surface of the vertebral canal. Each vertebra is strapped in the same manner to that which is above and below it, on that side of the interior of the tube which is next the semicircular body, and it is strapped in like manner to the next but one above and below it, and so on, as in the case of the anterior common ligament just described.

This system of ligamentous straps, extending longitudinally throughout the whole length of the vertebral canal along the posterior side of the bodies of the vertebræ, is called by anatomists the *posterior common ligament*, and its mechanical function obviously is to resist all undue forward strain of the spine.

81. The movements of the spine, like those of all other parts of the body, are produced by the contractile force of muscles inserted at suitable points upon its bony surfaces ; but when the form of the vertebral rings and bodies described above is considered, it will be obvious that no points of insertion could be found in them which would give to the muscular power any leverage at all proportionate to the great force which must be exerted in moving the mass of matter composing the trunk, the head, and superior members, the collective weight or inertia of which must necessarily react against such muscles. The structure of the spine, therefore, so far as we have described it hitherto, though fulfilling so many and apparently difficult conditions, would still be faulty in relation to the action of the muscles upon the mobility of the trunk and its appendages. We find accordingly, besides the provisions already described, others, which are specially appropriated to the solution of the muscular element of the problem.

From the part of the bony ring which is behind the points where it joins the body of the vertebra three levers project, two laterally and one from the centre of the posterior part of the ring. The two lateral projecting levers are denominated, from their direction, the *transverse processes*, and the centre lever is called the *spinous process*, this last being generally inclined more or less downwards. The ends of these levers are the points of insertion of various spinal muscles, which act

upon the vertebræ in the same manner as a mechanical power acts upon a rectangular lever. By these muscles, the spine, and with it the entire trunk and its appendages, is moved in various directions, as well laterally and obliquely as in the median plane.

A similar system of muscles are inserted in the anterior surface of the vertebral column, which may be regarded as antagonistic to those just described: the muscles on the posterior side raising the body and bending it backwards, while those on the anterior side cause it to incline forwards, and the muscles connected with the transverse processes incline it sidewards.

The slightest consideration of the form of the body will render it manifest that its centre of gravity is in front of the vertebral column; and, consequently, that by gravity alone there would be a continual tendency of the body to incline forwards. Such a tendency would obviously come in aid of the power of the muscles on the anterior side of the column, while it would oppose those on the posterior side. Hence arises the necessity for the powerful levers supplied to the latter by the spinous and transverse processes, and the absence of such aids to those in front of the column.

82. Having thus explained the various mechanical provisions from which the spinal column derives its functions, these explanations will be rendered more clear and satisfactory by

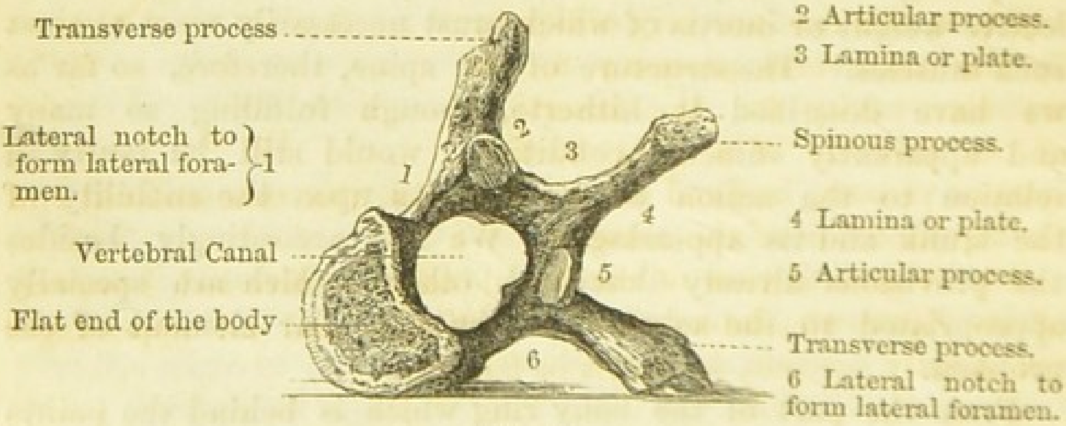


Fig. 20.

figures illustrating the several parts of that column and its appendages.

In figure 20, a view of a vertebra is shown, the line of sight being supposed to be at right angles to the flat semicircular surface of the body; and the names of the several

parts are indicated so plainly in the figure, that, after what has been explained, they cannot fail to be understood.

The spinous process as here shown must be understood to be inclined more or less downwards from the general plane of the figure, and therefore to be foreshortened. The two prominences with flat surfaces, called *articular processes*, are those by which each ring is connected with that which is above or below it. They are not generally in the direction of the semicircular surface of the body, but more or less oblique, and in some cases nearly at right angles to it. But, whatever be their direction, those of two vertebræ superposed correspond in position, figure, and magnitude, so that they come face to face parallel to each other. They are coated with cartilage, like other articulations, and are surrounded with a synovial membrane, by which they are lubricated. The pieces of bone connecting the body with the transverse processes are called *pedicles;* and it is in the borders of these, above and below, that the notches are formed by the combination of which the lateral foramina for the passage of the spinal nerves are formed.

A side view or profile of one of the vertebræ, taken from the middle of the back is shown in fig. 21, where 3 is the body; 1 and 2 the lateral notches; 4, 4, articular surfaces to receive the heads of the ribs; 5, 6, the articular processes described above, which in this case are very oblique; 7, the transverse process; 8, an articular cavity for the insertion of the tubercle of a rib; 9, the spinous process, inclined downwards; 10, the tuberculated end for the insertion of the muscles.

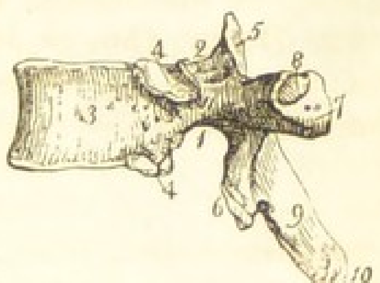


Fig. 21.

83. A general view of the spinal column, divested, however, of its ligaments, intervertebral cartilages, and all appendages not strictly osseous, is shown in fig. 22.

84. The component vertebræ are designated according to their numerical order, counting downwards from the highest, which immediately supports the head. They are usually grouped in three classes, and named according to their neighbouring parts. Thus, the first seven are called *cervical*, the next twelve *dorsal*, and the last five *lumbar*, making in all twenty-four distinct vertebræ in the adult. In infancy there are nine others, the first five of which, at mature age, are connected together by the ossification of the intervening cartilage, and the bone formed by the combination is called the *sacrum*. The four last, in like manner, coalesce by ossification and

form a single bone, called the *coccyx*, from a fancied resemblance to the beak of a cuckoo, for which bird coccyx is the Latin name.

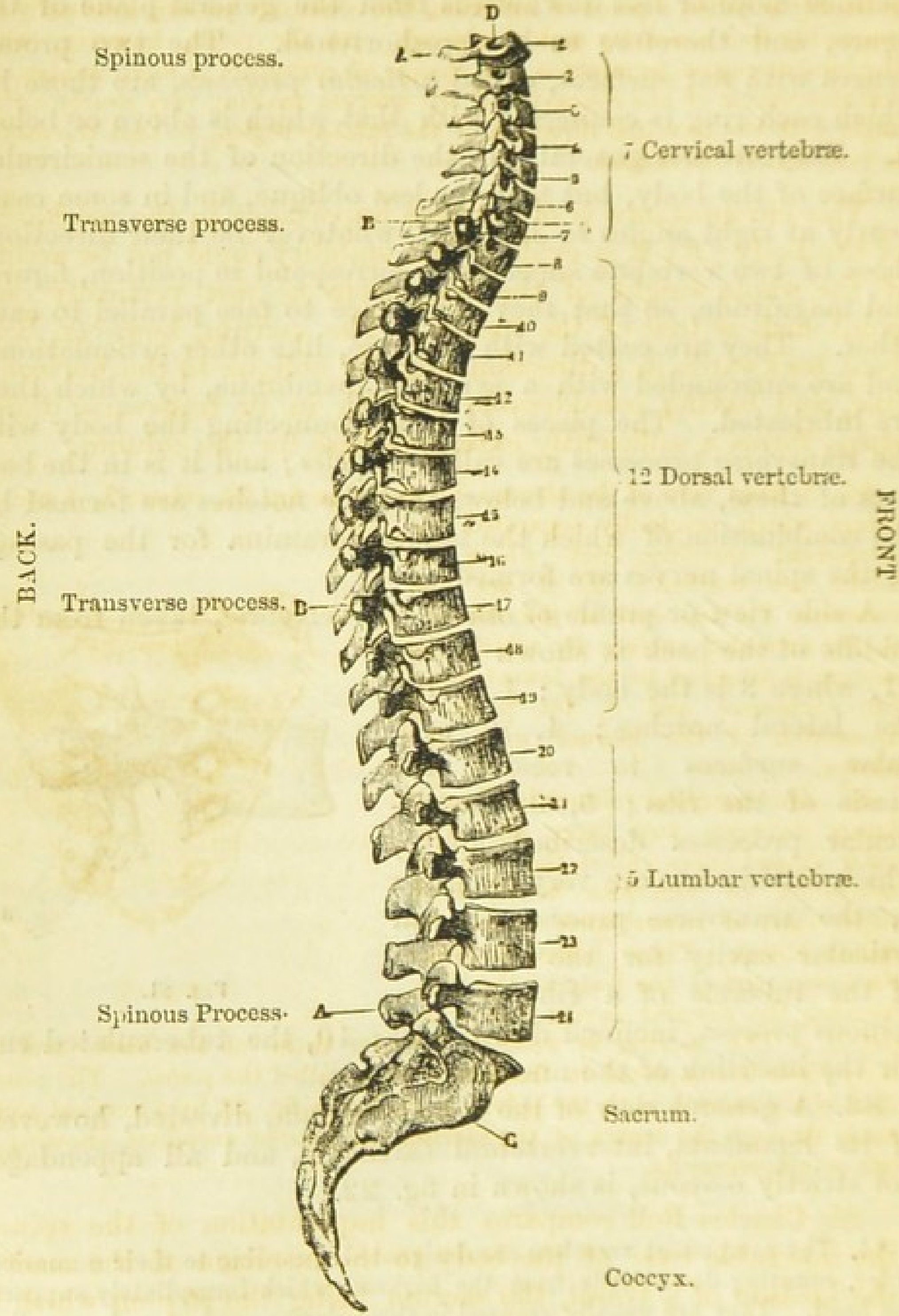


Fig. 22.

85. Thus it appears that the spinal column in mature age consists of twenty-six bones, of which twenty-four are *vertebræ*, and two others have the forms shown in fig. 22, being called the *sacrum* and *coccyx*. In its

normal position, the body standing upright, the vertebral column has curvatures, as shown in the figure, somewhat resembling an italic *ſ*. It is convex towards the front, in the cervical and lumbar, and concave in the dorsal and sacral regions. The changes of curvature are made by what in geometry is called a point of inflexion, the convexity passing gradually and insensibly into concavity and *vice versâ*. At the point, however, where the lumbar region terminates, the change of curvature is more sudden, the commencement of the concavity of the sacrum making very nearly a right angle with the terminal direction of the lumbar region, so that the sacrum is very nearly horizontal.

This circumstance is of extreme importance in the mechanism of the body; for it is evident that stability could not be secured if the whole weight of the body were to rest vertically on a point such as that of the coccyx. The sacrum, however, being bent backwards in a direction slightly oblique to the horizontal line, and having considerable breadth in its transverse dimensions, forms a sufficiently extensive base for the column.

86. A front view of the sacrum is shown in fig. 23, where 1, 1 are the ridges which originally separated the component vertebræ, but which in adults are ossified; 2, 2 are the foramina for the exit of the nerves; 6, the articular surface by which the sacrum is attached to the lowest lumbar vertebra; and 8, the point of connection of the sacrum with the coccyx.

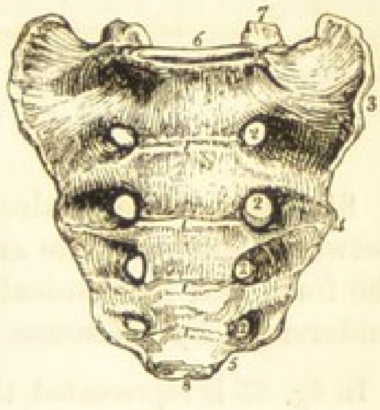


Fig. 23.

87. The vertebral column is planted firmly between two large and irregular-shaped bones called the *ossa innominata*, or nameless bones, from their want of resemblance to any familiar object. These bones surround the lower part of the body at the hips, forming the annular cavity called the *pelvis*. The sacrum is wedged between them at the back, and the bony circle is completed in front by a bone called the *pubis*. The connection of the sacrum with the pelvis is shown in fig. 24 by a vertical section made through the centre of the sacrum and lumbar vertebræ, showing the left os innominatum.

Sir Charles Bell compares this implantation of the spine in the moveable base of the body to the insertion of the mast in the keelson of a vessel, the sacrum being the *step* on which the base of the pillar, like the heel of the mast, is socketed and mortised. It is further secured by being tied down to the lateral parts of the pelvis by powerful ligaments, which may be compared to the shrouds by which the mast is bound to the sides of the vessel. These ligaments secure the lower

part of the spine against the effects of lateral motion or rolling.

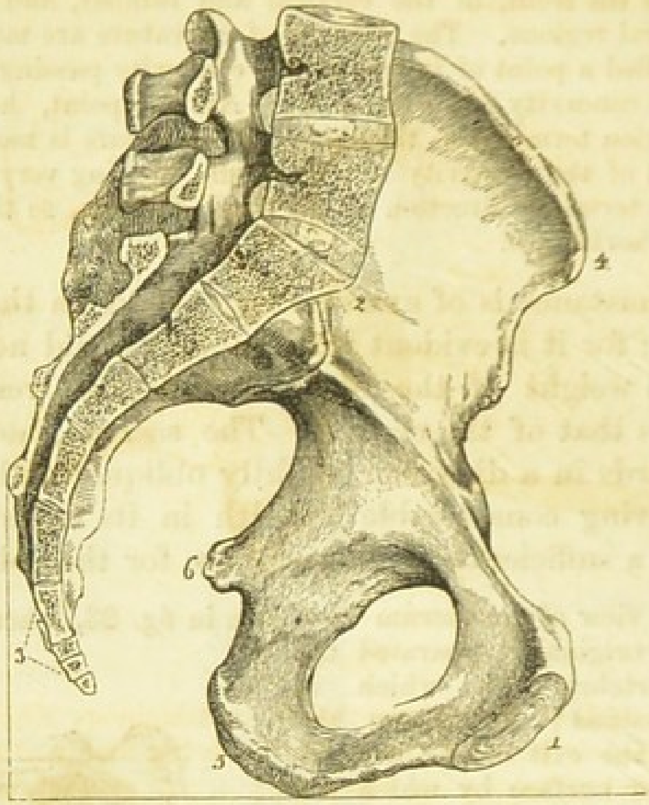


Fig. 24.

88. It has been already explained generally that the spaces between the vertebræ are filled by elastic cartilaginous discs; the form and mechanical effects of these will be more clearly understood by reference to the following figures.

In fig. 25 is represented the surface of one of these cartilaginous discs, placed upon the body of a vertebra. It consists of a series of concentric rings of cartilage, 25, ¹, placed one within the other, the interstices between them, as well as the central space, fig. 25, ², being filled with highly elastic pulpy matter.

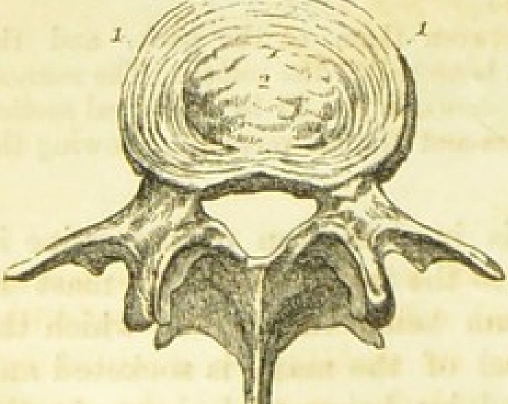


Fig. 25.

In fig. 26, a section of this disc made through the median plane is represented, the disc being supposed to be as in its natural state, compressed between two vertebræ. It will be seen that the concentric cartilaginous rings, 26, ¹, which are near the external part of the vertebra, are bent with their convexities outwards, while the internal ones, 26, ², have their con-

vexities inwards. The pulpy matter, 26, [3], is so elastic that, when it is relieved from the incumbent pressure of the upper vertebra, it rises up so as to assume a conical form.

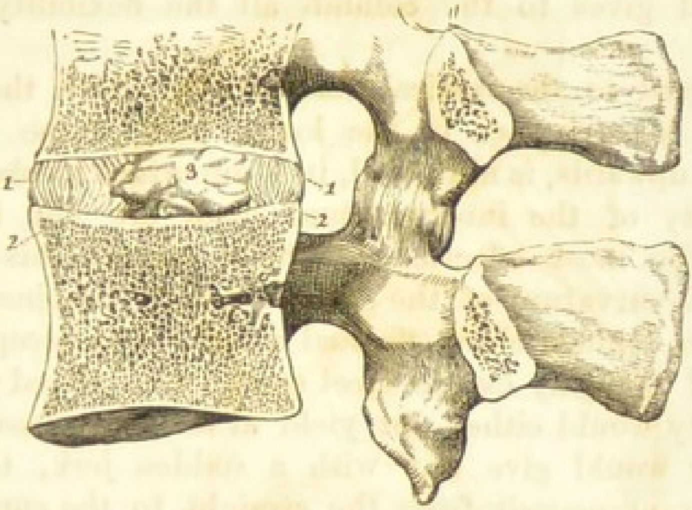


Fig. 26.

The fibres of each of the intervertebral cartilaginous rings are found to be extended obliquely between the vertebræ, being firmly attached at their extremities to the surfaces with which they are in contact. The direction of their obliquity varies from layer to layer, in one running from right to left, and in the next the reverse, fig. 27,[1], [2].

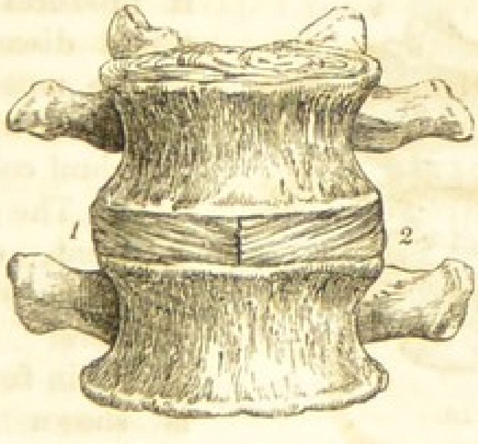


Fig. 27.

What has been here explained will render evident the admirable manner in which the spinal column acquires flexibility and elasticity, without impairing its stability or diminishing the protection afforded by its tubular canal to the spinal cord. The flexibility required is not the same in all parts of the column, more pliancy being obviously necessary in the cervical and lumbar than in the dorsal region. The inter-

vertebral discs are accordingly thicker where most pliability is needed. Although the pliability existing between any two contiguous vertebræ be inconsiderable, yet the combined effect of all gives to the column all the flexibility which is required.

With regard to the vertical elasticity by which the force of concussion, taking place in the lower part of the body and propagated upwards, is mitigated, it is important to observe that the elasticity of the intervertebral discs are not the only, nor even the most effectual provision against this injurious effect. The curvature of the spinal column, combined with its flexibility, is a much more effectual means of intercepting such shocks. If a highly elastic steel spring were placed vertically, the elasticity would either not yield at all to a pressure on its summit, or would give way with a sudden jerk, the spring passing instantaneously from the straight to the curved form. But, if such a spring, instead of being straight had the form of an italic *ſ*, it would yield gently and gradually to any force suddenly exerted upon either of its ends. The spinal column derives from its curved shape the same virtue. A sudden concussion acting upwards upon its base, instead of being transmitted without mitigation to the brain, is intercepted partly by the momentary compression it produces in the intervertebral discs, but much more by the momentary increase of curvature which it gives to the vertebral column.

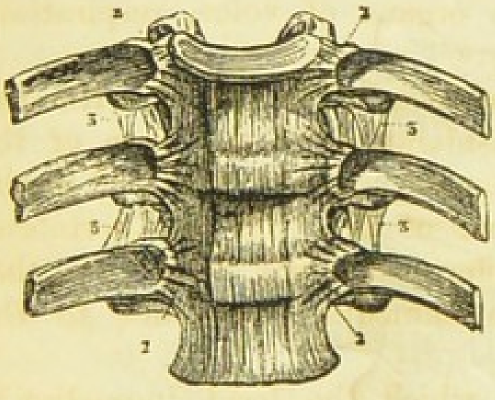


Fig. 28.

89. The anterior common ligament, or rather system of ligaments, by which the vertebræ are strapped together in front of the column, is shown in the case of three contiguous vertebræ in fig. 28.

After what has been explained, it will be understood that the exterior ligaments only are here visible, which connect distant vertebræ ; those which connect the nearer or contiguous vertebræ being under them. The ligaments by which the heads of the ribs are bound to the vertebræ, are shown in fig. 28, [2].

The posterior common ligament, such as it has already been described passing down the interior of the vertebral canal, is

shown in fig. 29[3]; the ring forming the remainder of the canal being sawed off to render it visible.

There are various other ligaments by which the rings around the vertebral canal are tied together, the principal of which, called the *supraspinous ligament*, connects the extremities of the spinous processes one with another, forming a continuous cord, or rather series of cords, extending from the lowest cervical vertebra to the base of the column. Like the anterior and posterior common ligaments, this consists of a system of superposed ligaments, the innermost connecting contiguous processes, the next alternate processes, and so on.

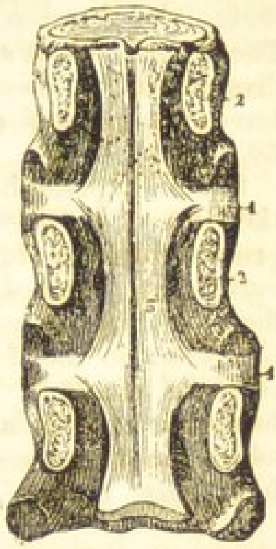


Fig. 29.

90. When the great freedom of motion possessed by the head in all directions, as well by inclination as by rotation, is considered, it may naturally be expected that the expedients by which it is connected with the vertebral column must present an example of a curious and interesting piece of mechanism; since it must not only provide for the free play of the head, but also for the security of the innumerable nerves and blood-vessels, and the conduits of the organs of voice, respiration, and nutrition, with the trunk.

The mechanism of the articulation of the head with the trunk not only includes the consideration of the form of the bony border of the foramen magnum, already described in the base of the skull, but also those of the first two vertebræ, which, as we shall now see, differ essentially from the other vertebræ in points which have immediate reference to the cervical articulation of the head.

91. The first vertebra, upon which the head immediately reposes, and called from that circumstance the *Atlas*, is shown by its upper surface in fig. 30, 1 being its anterior, and 4 its posterior side.

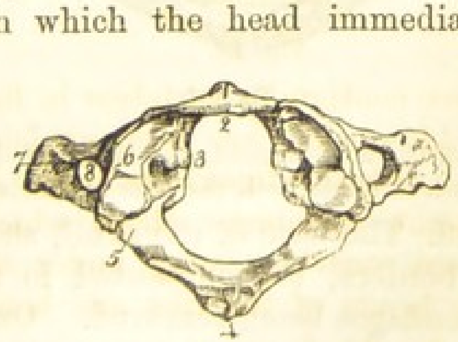


Fig. 30.

It differs obviously from the other vertebræ in having no semi-cylindrical body in front, the space which such a body fills in the inferior vertebræ being cut open so as to enlarge towards the front the aperture enclosed by the vertebral ring.

The spinous process is also wanting, or may be regarded as being represented in a rudimentary state by the slight projection, 30,[4]. The flat surfaces, 30,[6], are those upon which the articular surfaces of the skull bordering the foramen magnum rest, and with which they are articulated. The opening in the atlas being much wider from front to back than the diameter of the spinal cord, the latter passing through the posterior part leaves a large portion of the aperture unoccupied in front, extending from 30,[2] to 30,[3].

92. To explain how this space is filled, it will be necessary to consider the form of the second vertebra, called the *axis*, a side view of which is presented in fig. 31. This, like the atlas, differs essentially from the other vertebræ. The body in front, instead of being cut off to a flat surface flush with the general level of the bone, is continued upwards, 31,[2], somewhat in the form of a tooth, from which it has been called the *odontoid* process. When the axis is placed under the atlas, so that its foramen corresponds with the posterior part of that of the atlas through which the spinal cord passes, this odontoid process, 31,[2], passes into the front part, 30,[3],[2], of the aperture of the atlas, leaving a small space between it and the spinal cord. Across this space, binding the odontoid process, passes a ligament, 32,[2], which divides the entire aperture of the atlas into two unequal parts, the posterior part, 32,[3], being appropriated to the spinal cord, and the anterior part to the odontoid process.

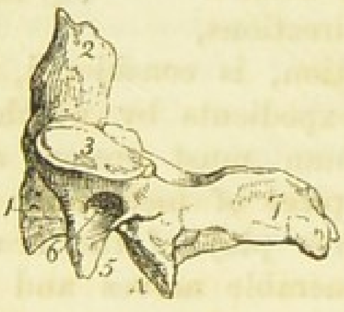


Fig. 31.

Another ligament issuing from the former upwards, 32,[1], and downwards, 32,[2], and therefore at right angles to it, is inserted into the odontoid process below the axis, and is continued upwards to the border of the foramen magnum in the skull. This crucial ligament, therefore, attains at once several important mechanical purposes. By its horizontal part, it binds the odontoid process in its place, and prevents it from pressing backwards on the spinal cord. By its downward branch it binds the odontoid process, and therefore the axis, to the anterior part of the atlas, and prevents the odontoid process from slipping downwards. By its upward branch it binds both the axis and atlas to the skull.

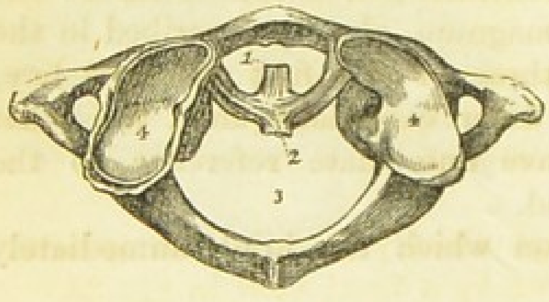


Fig. 32.

93. The base of the skull, showing the foramen magnum and its borders, is represented in fig. 33, the lower jaw and its appendages being removed. One of the surfaces on the border of the foramen magnum, which articulate with the atlas, is 33,[15], the corresponding surface on the other side being indicated but not numbered.

94. The atlas, the axis, and the skull are bound together by

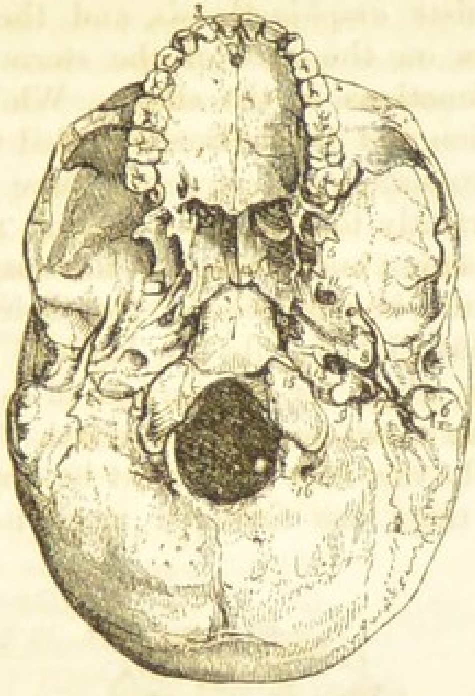


Fig. 33.

other ligaments surrounding the vertebræ, which need not be further particularised here.

It appears, therefore, that the odontoid process of the second vertebra is a pivot on which the first vertebra supporting the head turns ; and it is to this form of attachment that the head owes all that freedom of rotation, by which the face can be at will presented in any desired direction within the limits of the direction of the shoulders.

The faculty which the head possesses of being inclined in any direction forwards, backwards, laterally, or obliquely, is due to the flexibility of the cervical vertebræ.

95. **Thorax.**—The bony cage already described in general terms, called the *thorax*, is shown by a front view in fig. 34.

The ribs are articulated at their posterior extremities with the twelve dorsal vertebræ, and tied to them by ligaments as shown in fig. 28. In front, they terminate in cartilaginous straps by which the first seven, counting downwards, are connected with the *sternum*, 34, [4], or breast bone ; these seven are called *true ribs*. The other five likewise terminate in front in cartilaginous cords ; but these do not extend across the chest, each being connected with the cartilage of the rib above it, with the exception of the last, or twelfth rib, 34, [16], which, being loose and unattached to the others, is designated the *floating rib*. These five last ribs, not being directly connected with the sternum, are called *false ribs*.

This structure of the thorax produced by the combination of the slightly movable articulations of the ribs with the vertebræ, called by anatomists *amphiarthrosis*, and the flexible cartilaginous extremities on the side of the sternum, is admirably adapted to the functions of the chest. While the great vital organs of circulation and respiration included within the thorax have adequate protection, the structure here described accommodates itself perfectly to the never ceasing mechanical action resembling the opening and closing of the boards of a bellows, by which respiration is maintained. In their normal position, the oval rings formed by the ribs are inclined downwards from the vertebræ ; but when, for the purpose of inflating the lungs, the capacity of the chest must be enlarged, the ribs generally, and more especially the false ribs, must be drawn upwards, by which the oval rings are rendered more nearly horizontal.

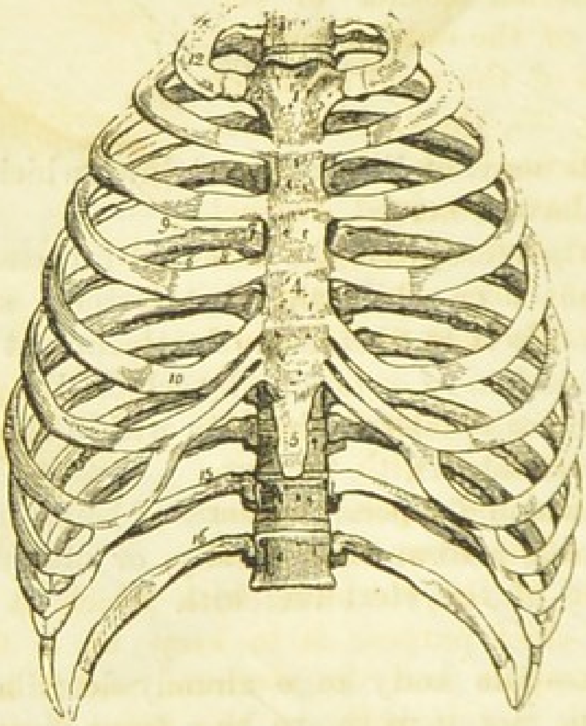


Fig. 34.

When, on the contrary, the air which has inflated the lungs is expired, the same bony rings are pressed downwards to their extreme limit, so as to diminish the capacity of the chest. In this manner, with every inspiration and expiration in the act of breathing, the ribs are moved alternately upwards and downwards, with an oscillating motion upon their articulations with the vertebræ ; and the perfection of the mechanism by

which this is accomplished, and that by which it has a self-restoring power, will be understood, when it is considered that that mechanism retains its functions usually for above seventy years sufficiently unimpaired for the maintenance of vitality, and sometimes even for a century ; the action being maintained without a moment's intermission, and being repeated thirty or forty times per minute, night and day, and sleeping or waking.

96. **The Scapula and Clavicle.**—At the summit of the trunk here described, a bony structure is attached, adapted for the support of the arms. This, on each side, consists of two bones, one posterior, called by anatomists the *scapula*, and popularly the "shoulder-blade," and the other anterior, the *clavicle*, popularly called the "collar-bone."

The scapula is a large, flat, triangular-shaped bone attached to the shoulder, and occupying the upper and external corner of the back. A view of the outside surface of the scapula of the right shoulder is shown in fig. 35, the various parts of which, indicated by the numbers upon it, have received distinct names in descriptive anatomy, which are unimportant here, and may be ascertained by reference to "Quain's Anatomy."

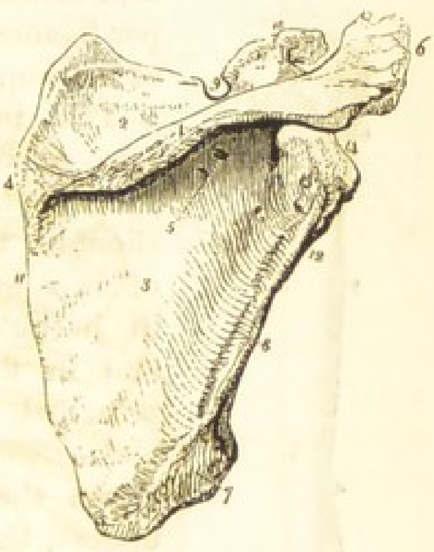


Fig. 35.

The clavicle is a slender and cylindrical bone articulated with the scapula at its external and superior corner 35,[6], and extending from that point to the summit of the sternum, with which it is also articulated. Its chief purpose is to keep at a fixed distance, asunder, the scapula and the sternum, and it has accordingly been compared, not inaptly, to the flying buttress in Gothic architecture. The two clavicles will be seen *in situ* by reference to fig. 11, where also the scapulæ are partially visible through the interstices of the ribs.

The mechanical effect of the two collar-bones thus interposed between the summits of the shoulders and the breastbone is to keep the shoulders apart and give them expansion, throwing them sufficiently beyond the vertical line of the ribs to leave free space for the play of the arms, as will be seen by reference to fig. 11.

The clavicles, as shown in fig. 11, are remarkably thin bones, incapable of resisting much strain applied to them laterally. This, which to bones otherwise placed might be a defect, is quite consistent with the functions assigned to the collar-bones, which are subject to no other strain than the longitudinal thrust which may arise from the tendency of the shoulders inwards towards the breast, which they are perfectly capable of resisting.

97. **The Arm.**—At the external corner of each scapula is found a shallow, spherical cavity, called the *glenoid cavity*, corresponding in form with the head of the upper bone of the arm. The edge only of this cavity, 35[14], is visible in the figure, the cavity itself being situated on the other side of the bone. The head of the upper bone of the arm articulated with it is retained there by proper ligaments, having, nevertheless, full freedom of motion.

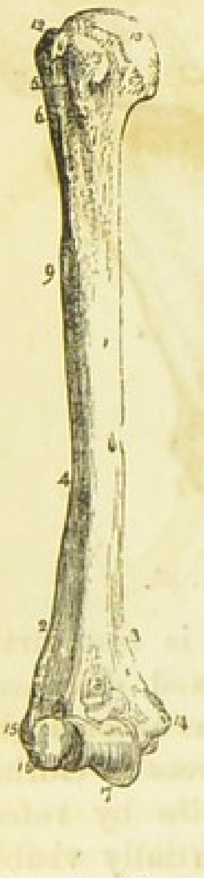


Fig. 36.

The upper member, popularly called the arm, consists of three parts : the arm, properly so called, or *humerus*, extending from the shoulder to the elbow ; the fore-arm, consisting of two bones of nearly equal length, placed in juxtaposition, called the *ulna* and *radius* ; and in fine, the hand, consisting of three principal parts—the *carpus*, or wrist ; the *metacarpus*, being that part of the hand between the wrist and the knuckles ; and the fingers, the bones of which are called *phalanges*.

The humerus, shown in fig. 36, is an irregular cylindrical bone, the superior extremity of which presents a hemispherical head, 36, [10], turned obliquely inwards towards the shoulder, and which, when in its place, is fitted in the corresponding cavity, 35,[14] of the scapula, above described. It is shown *in situ* in fig. 11.

The joint thus connecting the humerus with the scapula has in the highest degree the character of the ball and socket. The humerus is, by this joint, capable of taking any position within the limits of an extensive cone having its vertex in the joint. Thus, while, on the one hand, it may be brought into close contact with the ribs, it may, on the other, be elevated so as nearly or altogether to touch the side of the head. It may be presented directly forwards, or directly backwards, so that its play may more properly be said to be limited by a hemisphere than by a cone. This play, however, will greatly vary in different individuals, depending on peculiar

natural conformation, exercise, and age. In all, however, without exception, this bone has a greater play than any other member of the body.

This great range of motion is given to the arm partly by the form of the articulating surfaces of the shoulder-joint, and partly by the form and structure of the ligament surrounding it. While the head of the humerus, 36, [10], is hemispherical, the cavity behind, 35, [14], is a very shallow spherical depression, in which, consequently, the head of the bone can turn freely through a great range.

The ligaments by which the several bony pieces are connected together at the shoulder are shown in fig. 37, which represents the interior surface of the scapula of the right shoulder, or that surface which is laid against the trunk. The collar-bone is tied to its upper and external corner by two ligaments, one of which, 37, [1], appears in the figure, the other being behind the joint. This bone is also tied to the scapula at 37, [4], by the ligament 37, [2]. In a projecting corner of the scapula immediately under the point where the clavicle is articulated, is the shallow spherical cavity already described, in which the hemispherical head of the humerus plays, and this is loosely held in its place by ligaments, fig. 37, [5] and [6], which extend round the head of the bone.

The ligamentous connection thus formed between the arm and the shoulder is so loose, that when the surrounding muscles are removed, the head of the bone would fall out of the socket. It is, therefore, by the muscles rather than the ligaments that the bone is retained in the socket, the ligaments serving merely as a check to limit its play. The atmospheric pressure is also a very efficacious means of retaining the head of the humerus in its place (15).

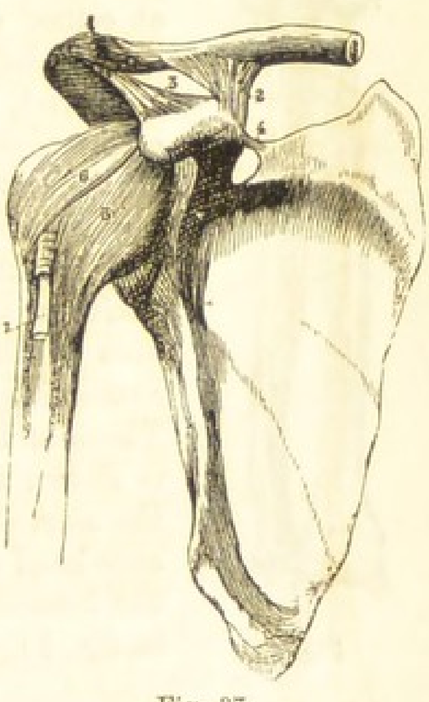


Fig. 37.

The lower end of the humerus, 36, [14] and [15], is formed into two semicircular pieces, called *condyles*, with flat and parallel sides, somewhat resembling those of the ends at which the legs of a compass are united. This extremity is articulated with the superior extremities, or heads of the radius and ulna, which have a form corresponding with that just described, so that the projecting parts of one entering the cavities of the other, and being tied together by proper ligaments, an articulation is formed which has the mechanical properties of a hinge or cradle-joint. Thus the fore-arm can be bent to the shoulder, or straightened, so as to form a line with the humerus ; but it is prevented from being inclined backwards by a projection from the end of the ulna, called the *olecranon*, which forms part of the extremity of the elbow.

By considering this hinge motion of the fore-arm, combined with the extensive range of motion of the humerus, it will be perceived how vast a play is given to the hand. In fact, it may be directed thus to any point placed within a large segment of a sphere whose centre is at the shoulder-joint, and whose radius is the length of the arm. When it is considered that in man the exclusive use of the hand is for the purposes of prehension and touch, the importance of this provision will be apparent.

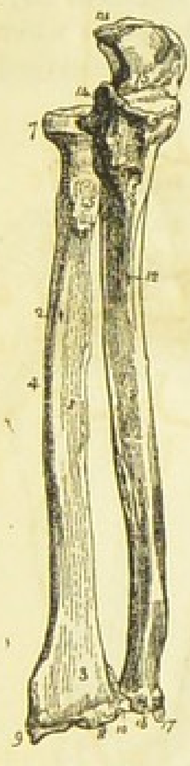


Fig. 38.

98. **The Fore-Arm.**—The radius, placed in juxtaposition with the ulna, is connected with it throughout its whole length by a strong fibrous membrane, and by ligaments at either end. At the lower end of the radius is an enlargement, to receive the articulation of the wrist, to which the hand is appended. The connection of the radius with the ulna is such, that it is capable of revolving round it, carrying with it the hand.

The ulna and radius in their natural juxtaposition are shown in fig. 38, which is a front view of the bones of the right fore-arm. The extremities of the radius are, 38, [7] and [9]. Those of the ulna, 38, [14] and [16]. The olecranon is shown at 38, [13]; and the large notch, called the *sigmoid notch* (38, [15]), together with the concave head of the radius, form the hinge-joint with the humerus. These bones may be seen *in situ* in fig. 11.

99. **The Wrist** consists of eight small bones ranged in two rows one above the other, and so placed as to surround and protect the blood-vessels and nerves which pass from the arm to the hand. For this purpose they form, combined with the surrounding ligaments, a short and strong tube which will bear great external force without being compressed. Although each of these numerous bones has but a very limited mobility in relation to the adjacent ones, their combination gives to the hand that freedom upon the wrist which is rendered manifest in the countless examples presented of nice and delicate manipulation.

The metacarpus is composed of a range of long thin bones articulated with the wrist-bones, four of which are placed parallel

and in juxtaposition, and are connected by ligaments at the knuckles, having very little independent motion, and forming the bones between the palm and back of the hand. To these bones are articulated the fingers. The first bone of the metacarpus has more play, and is inclined more towards the palm of the hand. At its extremity the thumb is articulated in such a position that it can at will be brought in opposition to each of the fingers, a faculty which is of the highest importance in all processes of manipulation.

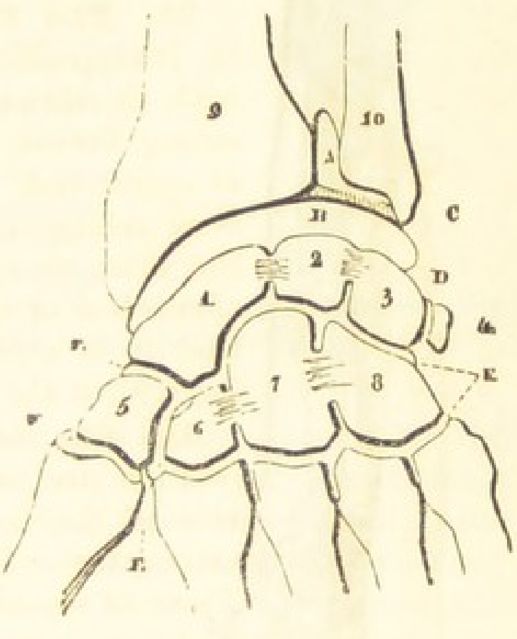


Fig. 39.

The forms and arrangement of the wrist-bones, and their positions relatively to those of the hand and arm, are shown in outline in fig. 39, where 9 is the radius, and 10 the ulna; 1, 2, 3, 4, the upper row, and 5, 6, 7, 8, the lower row of wrist-bones; the five metacarpal bones which extend from the wrist to the knuckles, appearing below, but cut off short. The fingers consist of three, and the thumb of two phalanges, which diminish gradually in length towards the extremities.

The ligament by which the humerus and fore-arm are connected at the elbow, the fore-arm and the hand at the wrist, and those by which the hands and fingers are connected, are shown in figs. 40 and 41. Fig. 40 represents a front view of the left arm and hand; the inside of the elbow-joint, and the palm of the hand, being supposed to be presented to the observer. Fig. 41 represents a back view of the same, the back of the elbow and the back of the hand being presented to the observer. It will be remembered that the radius is the outside, and the ulna the inside bone of the fore-arm, consequently the radius is on the rightof fig. 40, and on the left of fig. 41.

The bones of the humerus and fore-arm are connected together by a ligament attached to them above and below the elbow, and surrounding the joint like a glove. Although this ligament is thus continuous around the arm, it has been found convenient in the nomenclature of anatomy, to distinguish it as four separate ligaments,—one at the front, and another at the back of the joint, and the two others at the sides, called accordingly, the *anterior*, 40, [3], the *posterior*, 41, [4], the *lateral internal*, 40, [1], and *lateral external ligaments*, 41, [2].

Besides these which directly tie together the bones of the humerus and fore-arm, the radius is tied to the ulna by a remarkable ligament called the *annular* or *orbicular*, which cannot be distinctly seen in figs. 40 and 41, but is shown separately at 42, [5].

The radius and ulna are also tied together partly by a membrane, 40, [6], the fibres of which extend obliquely between them, called the

interosseous membrane, and partly by an oblique ligament, 40,[7], near their upper extremity.

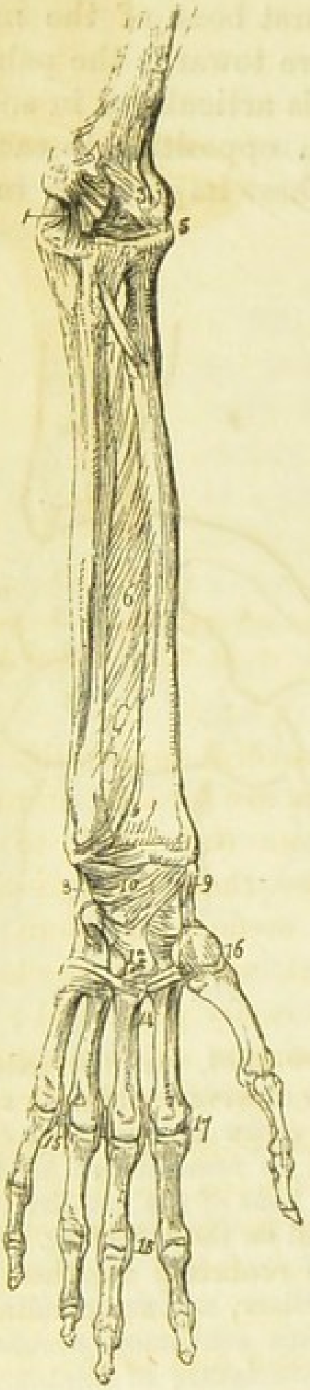


Fig. 40.

Fig. 41.

The lower extremity of the fore-arm is tied to the wrist by a continuous ligament which surrounds it like a glove, being, as in the case of the elbow-joint, distinguished in anatomy as four ligaments ; the *anterior*, 40, [10], the *posterior*, 41, [11], the *lateral internal*, 40, [8], and the *lateral external*, 40, [9].

The two rows of bones which compose the wrist are also severally connected by ligaments, which being within those just described, are not

apparent in the figures, but are indicated in fig. 39, where the places of the synovial membranes for the lubrication of the numerous joints are also shown. Thus, A is the synovial for the radius and ulna ; B for the radius and wrist ; C is opposite to a ligament which connects the radius and ulna, and lies between the two synovials just mentioned ; D is the synovial between 3 and 4, and E, E that between the two rows of wrist-bones, and also between the second row and the hand F being the synovial between the first bone 5, of the second row and the thumb.

Fig. 42.

The wrist is connected with the hand by two ligaments, 40, [12], on the side of the palm, and 41, [13], on that of the back of the hand ; the former being called the *palmar*, and the latter the *dorsal* carpo-metacarpal ligaments. The metacarpal bones forming the skeleton of the hand are connected together by intermediate ligaments, as well at the wrist as at the knuckles, shown at 40, [14] and [15] ; and the thumb has similar ligaments, the upper of which is shown at 40, [16]. The several finger-bones are also connected by ligament, all of which are shown in figs. 40 and 41.

100. It may be remarked that the several levers, by the combination of which the superior members are formed, diminish progressively in length in proceeding from the trunk to the extremities. Thus, the humerus is longer than the fore-arm, the fore-arm than the metacarpus, the metacarpus than the phalanges, and each phalange than that which succeeds it. The advantage of such an arrangement is easily perceived ; the articulations increasing in number in proportion as we approach the extremity of the member, give the greatest facility in directing the instrument of prehension to the object it is intended to seize. Thus, the humerus makes, as it were, the first rough approach to the object. The fore-arm, by its inflexion on the humerus, comes nearer to it ; the hand revolving on the ulna by means of the radius, the phalanges, with motions successively smaller and nicer, are brought nearer and nearer to the object until it is seized.

Every one who is familiar with the mechanical expedients adopted in philosophical instruments, will perceive the striking analogy between these arrangements and the mechanical contrivances by which the most extreme precision is attained in the observations made with them. There are two classes of adjustments always provided, designated by instrument-makers and observers as the coarse and the fine adjustments. By the coarse

adjustment, the instrument is brought promptly, but only approximately, to the desired position, which is afterwards attained with precision by the fine adjustment. Thus, in the mechanism of the arms, the motion of the humerus and fore-arm are the coarse, and the smaller and more delicate motions of the fingers, the fine adjustments.

101. **The Leg.**—Between the lower members and the upper there are obvious analogies ; thus, the hip and the shoulder, the knee and the elbow, and the ankle and the wrist, severally present resemblances of structure which are strikingly apparent. But, on the other hand, there are differences between the arms and legs, and their mode of articulation, which are not less striking, all of which have relation to the peculiar functions of each member, the superior being adapted exclusively for prehension, and the inferior as exclusively for locomotion.

The pelvis, as already explained, is a shallow basin, concave upwards, the bottom of which is open, or rather filled with muscular tissue ; it forms the base, as the scapulæ and clavicles form the summit, of the trunk. The two pelvic bones, already mentioned, called the *ossa innominata*, placed partly behind and partly at the sides, forming the hips, are analogous to the scapulæ which form the shoulders, and they are connected in front by the bony arch called the *pubis*, exactly as the scapulæ are connected by the clavicles. This will be perceived more evidently by referring to fig. 11, where all the bones are shown in their proper relative position, with their names annexed.

102. At the external corners of the hip-bones are two deep hemispherical cavities looking obliquely downwards, intended to receive the spherical head of the *femur*, or thigh-bone.

This bone, which is the longest and the largest in the skeleton, extending from the hip to the knee, is represented in fig. 43, and consists of a rather irregularly cylindrical shaft, 43,^{1}, terminating above by a hemispherical head, 43,^{5}, formed upon a neck, 43,^{4}, bent obliquely inwards towards the hip, and below by an enlargement, 43,^{10} and ^{12}, at the bottom of which there is a cavity, 43,^{8}, of which the vertical section made by a plane passing from front to back is circular, being the form required to produce a hinge-joint. The direction of the neck, 43,^{4}, is such that the head, 43,^{5}, is presented to the spherical cavity already described at the corner of the hip ; and the joint thus formed has, therefore, the cha-

racter of the ball and socket, and is analogous to that of the shoulder.

Between them, however, there is a difference of form, which has an evident relation to their peculiar functions. The socket of the shoulder, as has been already explained, is extremely shallow, and consequently gives a very wide play to the arm. But this shallowness gives little security to the maintenance of the bones in their relative position, which is therefore effected altogether by the ligaments and surrounding muscles; greater strength of connection not being required, since the bone and socket are not urged together by any considerable pressure.

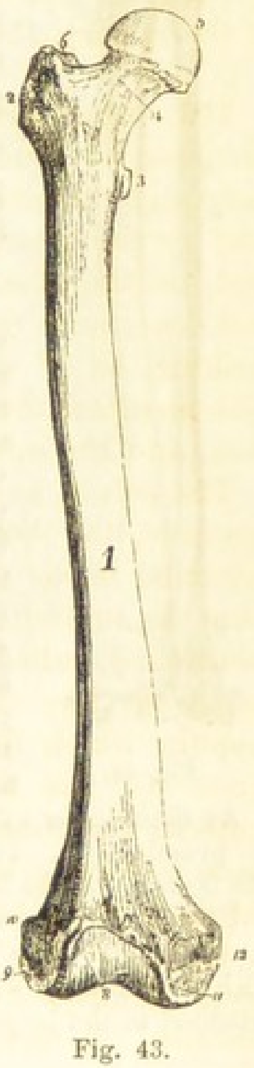


Fig. 43.

In the case of the hip-joint, however, the mechanical conditions are totally different. Although, for the purposes of locomotion, the play given by the ball and socket principle to the leg is requisite, the same large extent of play as is necessary for the purpose of prehension in the arm is not at all required. On the other hand, the looseness of mechanical connection, which must necessarily attend a socket so shallow as that of the shoulder, would be totally incompatible with the firmness and stability necessary to render the legs a secure support for the incumbent weight of the body. Indeed, by merely inspecting the relative position of the bones, shown in fig. 11, it will be apparent that if the socket of the hip, in which the head of the thigh-bone is articulated, were as shallow as that of the shoulder, the weight of the body alone, not to mention the thousand external disturbances to which it is exposed, would have a continual tendency to produce its dislocation.

The hip-joint is surrounded by a ligament and other fibrous coverings, which connect together the bones in the same manner as the ligaments already described connect together those of the shoulder. But in the case of the hip there is an additional ligament, called the *cotyloid*, which is a fibrous ring surrounding the edge of the spherical socket, increasing its depth, and completing its border where the bone is deficient.

103. The leg, which extends from the knee to the ankle, consists like the fore-arm of two bones, placed parallel to each other, in contact at their extremities, but separated by an intermediate space throughout their length. One is much thicker than the other, and is called the *tibia*, from a Latin word, which signifies a pipe or flute. The other is comparatively thin, and is called the *fibula*, a Latin name, signifying the pin of a brooch, and sometimes the *peronea*—a Greek word, having the same signification.

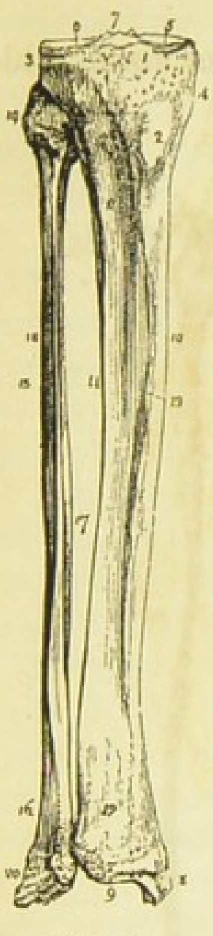


Fig. 44.

The resemblance from which this name has been taken will be apparent by reference to fig. 44, which presents a front view of the right leg, the tibia, 44,[13], and the fibula, 44,[15]. The head of the tibia, 44,[4], terminates at the superior part by two surfaces, 44, [5] and [6], coated with cartilage, between which is an eminence, 44,[7], which articulates with the lower extremity of the thigh-bone. When the tibia is articulated with the femur, the projecting parts of the latter, 43,[9] and [11], rest upon the cartilaginous coatings, 44,[6] and [5], the eminence, 44,[7], entering the cavity, 43,[8]. This articulation is covered in front by a bone called the *patella*, or knee-pan, on which the tendons of the muscles which move the leg play like ropes over a fixed pulley.

At their lower extremities the tibia and fibula throw out two processes or prominences, 44,[8] and [20], which form the ankles, the former being the inner, and the latter the outer one.

Unlike the bones of the fore-arm, those of the leg do not admit of revolution one round the other ; and the foot, instead of being articulated with the fibula, which corresponds to the radius, is more immediately attached to the larger extremity of the tibia.

104. **The Foot.**—The foot, like the hand, consists of three principal parts ; the *tarsus*, or upper instep, extending from the ankle to the point where the foot turns horizontally ; the *metatarsus*, or lower instep, extending from the latter point to the origin of the toes ; and, in fine, the toes, the bones of which, like those of the fingers, are called *phalanges*.

A view of the bones of the foot seen from above, is shown in fig. 45, and one as seen from below in fig. 46.

The highest bone, 45,[11], of the instep, resting upon all the others, is pulley-shaped, its vertical section from front to back being circular, the sides, 45,[12] and [13], are flat, and a projecting base, 45,[10], extends below it. This bone, 45,[11], entering between the ankles, 44,[8] and [20], forms the articulation of the foot with the leg, or what is called the

ankle-joint. This bone, which is called the *astragalus*, has, therefore, the motion of a hinge between the ankles.

Fig. 45.

Fig. 46.

Under the astragalus, extending to some distance before and behind it, are six other bones, the principal of which is that of the heel, 45, [7]; another, 45, [21], is placed under, and a little in front of the astragalus; and the four others, 45, [23], [24], [25], and [15], are placed between these and the five metacarpal bones, which extend along the instep to the origin of the toes. The form and arrangement of these latter are peculiar, and worthy of attention. They form an arch, being curved both laterally and forward, so that a line drawn over the surface of the foot from the instep to the origin of the great toe would, in a well-formed foot, be convex upwards, and a line drawn across the foot from the inside to the outside would also be convex upwards. But its convexity would be turned rather outwards, commencing at an elevated point on the inside, and extending to the point where the sole touches the ground on the outside.

This arched or dome-like form of the bones of the foot is attended with several mechanical advantages, among which may be mentioned the protection it affords to the vessels and nerves which pass from the leg to the foot, and the firmness and elasticity which it gives to the foot, both as the basis of support for the weight of the body, and as its principal instrument of locomotion.

The ligaments by which the upper extremities of the bones of

the leg are connected with the lower extremity of that of the thigh, are shown by a front view of the left knee in fig. 47, and by a back view in fig. 48.

As in the case of the other principal articulations, these ligaments

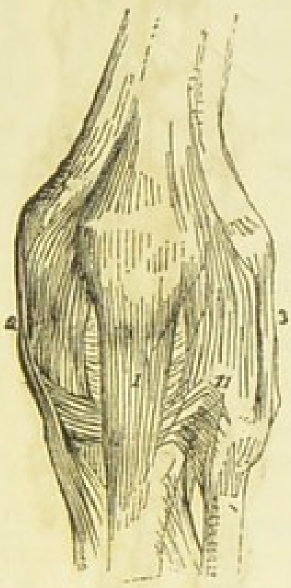


Fig. 47.

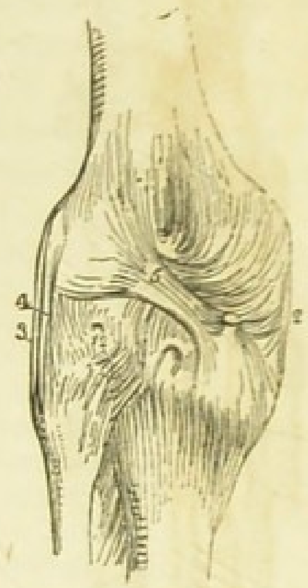


Fig. 48.

completely envelope the joint. They are, however, classed by anatomists as four; the lateral being 47,[2],[3], the posterior, 48,[5], and the anterior, called the ligament of the *patella*, fig. 47,[1]. Besides these, the bones are connected by two other ligaments which are concealed in the figures, and are called the *crucial* or *oblique* ligaments of the knee.

The two bones composing the leg are connected together by an interosseous membrane, 49, [2], and anterior ligament, 49, [1], and a similar posterior one not seen in the figure.

The ligaments connecting the bones of the ankle and foot are shown in fig. 50, where the sole is presented to the observer. Each of the seven bones composing the instep are tied together by independent ligaments, and the metacarpal bones and phalanges of the toes are connected by ligaments so similar to those of the hand that they need no special description.

A side view of the inner ankle is given in fig. 51, and of the outer in fig. 52. The foot is here shown to be connected with the leg by four ligaments, one (51,[6]) extending from the inner ankle to the heel-bone and laterally over the instep at 51,[7], and backwards towards the heel at 51, [10]. The tendon, 51, [8], extending upwards towards the calf of the leg is that well known as the tendon of *Achilles*. The anterior and posterior limits of the astragalus are shown in 51,[2].

The three other ligaments (52, [6], 52, [7], and 52, [8]) have their origin in the outer ankle (52, [2]), the first being distinguished as the anterior, the second as the middle, and the third as the posterior. The anterior and posterior ligaments are inserted in the anterior and posterior parts of the astragalus, and the middle ligament in the heel-bone. The external

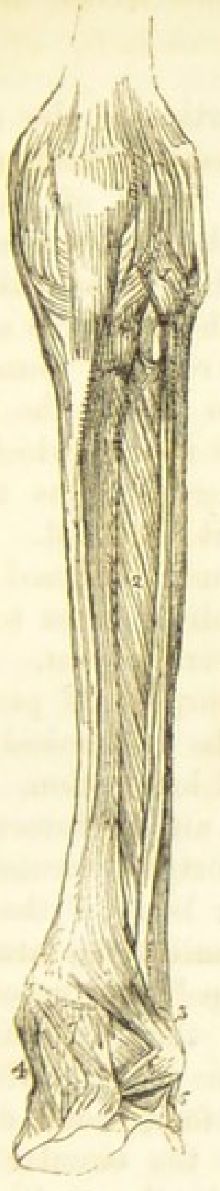


Fig. 49.

Fig. 50.

Fig. 51.

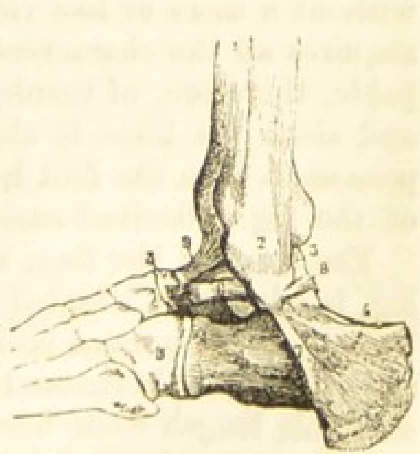


Fig. 52.

ankle is also bound to the foot by a bundle of fibres spread over the instep (52, [9]).

105. In comparing the mechanical properties of the ankle with the wrist, their adaptation to the respective functions of the foot and hand is very conspicuous. The organ of prehension and touch requires to be presented with promptness and facility in all directions. We accordingly find it articulated, not to the ulna, which, being hinged upon the humerus at the elbow, is incapable of having that motion of rotation round its longitudinal axis which would be necessary to enable the hand to present itself in all directions—but to the radius, which, as already explained, is so articulated with the ulna, as to be capable of revolving round it, carrying with it the hand. This motion of rotation, given to it by the radius, combined with the hinge motion of the wrist upon the radius, gives to the wrist the mechanical properties of the universal joint. This mode of connection, perfect as it is for the purpose of prehension, would, however, be incompatible with the mechanical conditions necessary for an organ of support and locomotion. We find accordingly, in the foot, which is not an instrument of prehension, but where the conditions of support and locomotion are indispensable, that the second and lesser bone of the leg, the fibula, which corresponds to the radius, unlike the latter, is articulated with the tibia, so as to be incapable of revolving round it. This permanent connection fixes the inner ankle, formed by the projection of the tibia, and the outer ankle, by the projection of the fibula. They, therefore, hold firmly between them, like the plates of a hinge, the circular projection of the astragalus. They thus restrain the position of the foot laterally, so as to prevent it from turning on the ankle without a more or less violent strain. In short, the ankle thus acquires all the characters of a hinge-joint. The foot is incapable, therefore, of turning on the ankle inwards or outwards; and since the knee is also a hinge-joint, the power which we possess to turn the foot horizontally round the longitudinal axis of the leg is derived entirely from the hip-joint.

The form of the foot, as well as its position relatively to the leg, is admirably adapted to the support and locomotion of the body. In its normal position it is at right angles to the leg; and, therefore, horizontal when the leg is vertical. It has considerable length from heel to toe, so that the two feet give a large base for the support of the body. Such a base is formed

by the quadrilateral figure produced by drawing lines connecting the extremities of the toes and heels. The heels projecting backwards, the posterior side of this base of sustentation falls behind the line of direction of the centre of gravity of the body, as the line joining the toes forming its anterior side falls before it.

Owing to the arched form in which the bones of the foot are arranged, the sole of the foot is not a uniformly flat surface, being concave under the inner ankle, so that its line of contact with the ground may be considered as a semi-circle, or rather a semi-ellipse, the convexity of which is presented outwards, the extremities of the curve being the part of the heel which rests upon the ground, and the ball of the great toe. This form is attended with obvious advantages. If the sole of the foot were absolutely flat, it would be much more liable to injury by the inequalities of the ground, while it would afford no greater base of sustentation than is given by the semi-elliptical line of contact just described.

By the combined effects of the ankle, knee, and hip-joints, the centre of gravity of the body in the act of walking, or running, advances forward in a line nearly horizontal. Without the flexibility of the knee and the hip, the body carried over the hinge-joint of the ankle would, in making each step, cause its centre of gravity to be moved in the arc of a circle, concave downwards. That centre would be raised in the first half of the step, until the leg would take the vertical position, and it would then fall. Thus, the action would consist of an alternate elevation of the whole weight of the body, succeeded by a jolt, or shock, produced in its descent. This, however, is prevented by the knee-joint bending slightly, as the body advances over the leg.

CHAPTER III.

THE MUSCLES.

106. In the animal economy, no organs occupy so large a space as the muscles. They constitute nearly the whole of what is commonly called *flesh*, being that part of the animal which, when used as food, is distinguished from the fatty parts by the term *lean*. It is to the conformation of the muscles that the body owes all the finer details of its external appearance. The bones, maintained in their proper relative positions by the ligaments, confer upon the body only its general outline. But all its finer and more delicate details, and more especially those by which individuals of the same species are characterised and identified, are due to the peculiar form and development of the muscular system. We accordingly find no parts of the body vary so much with age and sex, with the sanitary state of the individual, and with personal occupation. No organs are so conspicuously affected by exercise, or the want of it. By gradually increased action, without being over-strained, the development of the muscles is most remarkable. Thus, they are frail and feeble in children, in females, and in all those who by habit or profession are speculative and sedentary; while, on the other hand, they are conspicuously enlarged in all, who, being otherwise in good sanitary condition, are devoted to laborious pursuits.

As may be expected, the particular muscles which are most called into play in each occupation, are those which are most developed. The arms of the blacksmith are like those of the statue of Hercules, though his legs may, at the same time, show the more delicate forms of the Apollo. The haunches, thighs, legs, and feet of a stage-dancer, exhibit a striking example of muscular force, the flesh being nearly as hard as bone, while the arms are comparatively puny.

107. When the muscular power of individuals is, so to speak, preternaturally increased, whether in the case of the training of a race-horse, the practice of an opera-dancer, or the exercise of pupils under the calisthenic system, it is not enough that the exercises should be prosecuted gradually, but each day's prac-

tice must be preceded by a tiresome preparation. In gymnastic establishments, for example, the pupils begin by walking for a certain time round the arena, after which they run, first gently, and then more rapidly, until their muscular system is brought to that state of elasticity and vital energy, which is necessary for the safe display of the higher feats of strength and agility.

Although this department of physical education is, when properly conducted, productive of incontestable advantages, it is one which, in the opinion of high medical and physiological authorities, is not unattended with danger. "By such system of gymnastics," observes Sir Charles Bell, "children are urged to feats of strength and activity, neither restrained by parental authority, nor even left to their own sense of pleasurable exertion. They are made to climb, to throw their limbs over a bar, to press their foot close to their hip, their knees close to their stomach, to hang by the arms and raise the body (thus reversing the natural action of all the muscles), to hang by the feet and knees, to struggle against each other by placing the sole of their feet in apposition, and to pull with their hands. No doubt, if such exercises be persevered in, the muscular powers will be strongly developed. But, the first question to be considered is, the safety of this practice. We have seen a professor of gymnastics, by such training, acquire great strength and prominence of muscles; but by this unnatural increase of muscular power, he became ruptured on both sides. The same accident has happened to boys too suddenly introduced to such exercises."

108. How necessary a gradually increased system of action is to the due development of muscular power, is proved by the treatment of horses, and especially those destined for the extraordinary exercise of racing. A person who receives a horse fresh from the stables of a dealer, is often surprised and disappointed to find that in a week or two he falls out of condition, and infers, often too inconsiderately, that he has been overreached; when, in fact, the cause of the animal's decline of condition is merely the sudden transition from the quiescence of the dealer's stable, accompanied by a régime suitable to it, to a state of regular work and a different régime. The purchaser, in such cases, may consider himself fortunate if a temporary falling off of condition be the worst evil which ensues, inflammation and congestion of the lungs being a possible and not at all improbable consequence of such proceedings. By a regulation of the army, when young horses

are brought into a regiment, they are walked an hour a day for the first week; two hours for the second week; and three hours for the third. They are then walked till they are fatigued, but not sweated; and by continuing the same very gradual increase of exercise, are at length brought into regular working order.

Race-horses, under three years old, are in like manner brought very slowly to their exercise, beginning with the lounge, after which a very light weight is put upon them, which is gradually increased to the prescribed limit. Nothing can show in a more striking point of view the effects of exercise in perfecting the muscular action, than the consequences which often arise from the loss of one day's training. It will bring the favourite to the bottom of the list, and that without any suspicion of lameness, but from a knowledge of the fact acquired by experience, that even such a slight irregularity in his training will have a sensible effect upon his speed.*

109. Although the contraction of a muscle is necessarily succeeded by its relaxation, the muscle in that state of relaxation is, nevertheless, not absolutely inert or flaccid. The relaxation, therefore, which the muscles have in a state of repose, must be understood rather in a relative than absolute sense. They are always, whether acted on by the nerves or not, in a certain state of tension, the force exerted by each being equilibrated by a corresponding force of the antagonistic muscles. Thus, the parts of the body subject to voluntary motion may be understood, when in a state of repose, to be in a mechanical state similar to that of a lever which is loaded with weights, which are reciprocally as their distance from the fulcrum, the normal tension of the muscles connected with a member in a state of repose being necessarily subject to a like mechanical condition. It is supposed that this normal tension of the muscles, like the more intense contraction which results from the dictate of the will, is due to the stimulus of the nerves; but this stimulus, like that produced by the great sympathetic system, is independent of the will. According to this doctrine, therefore, which appears to be generally accepted, the nerves, independent of the will, maintain a constant action on the muscles; and the power of the will consists in either augmenting or diminishing the intensity of this action within certain limits.

110. The force with which a muscle contracts, other things being the same, will be proportional to the number of muscular

* Bell, Animal Mechanics, p. 29.

fibres, and therefore to the area of the section made by a plane at right angles to the fibres. But, it will also obviously be proportionate to the individual force of the component fibres, and to their density, the last mentioned circumstances being dependent upon the state of nutrition of the muscle, and the perfection to which it has been brought by exercise. There is nothing, however, in the organisation of the body more truly wonderful than the precision with which the will acts upon the muscle. The force transmitted appears to be conveyed from the sensorium, separately, to each component fibre of the muscle ; and it is measured so nicely that the resultant of all these elementary forces, countless in number, has exactly the intensity which is desired.

Nor are the conditions which determine the direction of the force less wonderful than those which fix its intensity. This direction is often determined by the combined action of two or more muscles, to each of which a force must be conveyed by the will, such that, when combined according to the mathematical principle of the composition of forces, these several components shall produce a resultant having the desired direction and intensity.

111. A very erroneous estimate of the functions of the muscular system would be formed, if it was regarded as a mere apparatus for the production of motion: so far the contrary is the fact, that it may be stated with truth that the voluntary muscles are much more habitually in a state of statical than dynamical action, and we must not here be understood to imply merely that state of muscular tension in which the muscles exist when not under the immediate operation of the will. There is no position of the body, while we are awake, however stationary it may be, in which innumerable voluntary muscles are not in a state of statical action. If we stand erect, the muscles which hold the lower members in a state of extension, and those which support the spine and head in the erect position, must be in a state of voluntary tension. If we sit with the back unsupported, the same will be true of the vertebral column and the head. If the back alone be supported, the same will be true of the head. All this will be most apparent, if we consider that, the moment the control of the will is suspended by sleep, all the joints become relaxed, the knees and hips sink, the spine bends forward, and the chin falls upon the breast. In fact, in such a state, all the movable parts of the body fall into that position into

which their gravity would bring them by the common laws of mechanics.

112. But as the statical tension of the muscles is as much an exertion of vital force as their dynamical contraction, it is necessarily followed by a sense of fatigue and exhaustion, and requires intervals of repose. When a person stands erect, the muscles of the legs, back, and neck being in a state of tension, soon become fatigued. If he sit upon a bench without a back, those of the legs are relieved, but the dorsal and cervical muscles are still in action. If he sit on a chair having a back, the cervical muscles alone are in action ; and if the back of the chair be sufficiently high and otherwise adapted for the support of the head, the cervical muscles are partly, but not altogether, relieved, as is proved by the fact, that if he fall asleep in that position, the chin will fall upon the breast, showing that while awake it was supported by the voluntary tension of the muscles of the back of the neck.

Even in the position here supposed, the muscles of the arms are not altogether in repose ; and, to give complete relief, the arm-chair has been invented.

113. It is not merely to the voluntary muscles that repose alternated with action is indispensable ; and it may therefore be asked, how such occasional repose is secured to the involuntary muscles, these being permanently removed from the dominion of the will, and their action being indispensable to vitality, even during sleep. We find in this case another of those countless evidences of the infinite beneficence and wisdom with which the Creator of the universe has provided for the well-being of the most minute and insignificant, as well as of the most exalted, of the creatures which he has called into existence. All the functions which depend for their play upon the action of the involuntary muscles are essentially intermitting, so that, although these may in a certain sense be pronounced to be in a state of never ceasing action, from the moment at which animal vitality commences, until that at which it ceases, the tension of the muscular fibres is not continuous, but is regularly alternated with intervals of relaxation, however short ; so that if the sum of all the intervals during which these muscles are relaxed in the whole duration of the life of an individual were taken, it would be found to be equal to the sum of the intervals of their tension.

114. Certain recent physiological researches have led to the discovery that the contraction of the muscles is not a uniform

mechanical effect resembling the tension of a spring or of a cord having a weight suspended to it; but that it is an act compounded of an infinite succession of partial and momentary contractions, which are continually shifting their place on the muscular fibres. This fact, which seems to have been ascertained by direct observation by Mr. Bowman, is in remarkable accordance with a muscular phenomenon first noticed by Roger, and described by him in a work published at Göttingen, in 1760, but which was since much more fully investigated by Dr. Wollaston. This phenomenon consists in a certain sound produced by the muscles in contracting, which Dr. Wollaston described as resembling the distant rolling of a carriage, and which Roger expressed by the Latin word *susurrus* (a low murmuring noise). This acoustic phenomenon is therefore explicable, if the vibrating motion of the muscles in contracting, as described by Mr. Bowman, be admitted.

115. **The Muscular Sounds**, whose vibrations have been ascertained to take place at the rate of twenty to thirty per second, have recently been submitted to examination by scientific medical practitioners, and their variation has been shown to be so connected with the phases of certain maladies, that their observation with the stethoscope has been admitted as an important diagnosis in medicine.

116. **Number of Muscles.**—When the infinite variety of motions of which all the parts of the body are susceptible is considered, and when it is remembered that a single muscle can only produce motion by drawing nearer to each other its origin and insertion, it cannot but be expected that the muscles should be extremely numerous. We accordingly find them variously estimated by different authorities. Thus, Theile gives them as 346; Chaussier as 368; and Sir Charles Bell as 436. They may, therefore, be stated generally, in round numbers, at about 400.

It might be supposed that this great discrepancy between different and equally eminent anatomical and physiological authorities must arise from an imperfect knowledge of the structure of the muscular system. Such, however, is not the case; the difference being entirely in words, and not at all in things. If each muscle had a single point of origin, and a single point of insertion, no difference would have existed in their enumeration. But such is not the case. Muscles which

have a single origin often have two or more insertions, and those having a single insertion have two or more origins. Anatomists are not agreed, in such cases, whether these are to be regarded as single or as so many independent muscles.

117. **Classification.**—Although the nomenclature of the muscular system is extremely complicated, and perhaps needlessly so, it is, nevertheless, very significant and expressive. Muscles are named and classed, either from their form, their position, or their action. Thus we have the *deltoid*, the *dentelated*, the *rhomboidal*, the *square*, the *triangular*, the *scalene*, the *long*, the *oblique*, &c.; all which terms explain themselves, being obviously taken from the approximate form of the muscle. Then we have them grouped according to the region of the body in which they are placed: those of the face being called the *facial;* those of the arms the *brachial;* those of the breast the *pectoral;* those of the back the *dorsal;* those of the neck the *cervical;* those of the hips and haunches the *pelvic;* those of the legs the *crural;* and so on.

118. **Nomenclature.**—But the most important principle of the muscular nomenclature, at least for our present purpose, is that which depends on the action of the muscles. Thus, when a movable part is bent with a hinge motion, like the knee or the elbow, it is necessarily placed under the action of two muscles, one of which inflects the parts towards each other, and the other extends them into a straight line. The muscle by whose contraction the former effect is produced is called the *flexor*, and that which produces the latter the *extensor* muscle. Thus the flexor muscle of the leg extends from the back of the thigh to the back of the leg, and the extensor muscle from the front of the thigh to the front of the leg, passing over the knee-pan.

Muscles are also denominated according to the direction in which they move a member with relation to the trunk. Thus the muscle which moves the arm *from* the trunk is called *abductor*, and that which moves it *to* the trunk *adductor*. A muscle which lowers a member is called a *depressor*, and one which raises it a *levator*. A muscle which expands a part is called a *dilator*, and one which compresses it a *compressor*; and so on.

119. The general symmetry which prevails in the structure of the animal body, and which has been already indicated in

the distribution of the bones and their appendages on either side of the median plane, necessarily suggests a corresponding distribution of the muscles. Like the bones, they are therefore, with a few exceptions, formed in pairs, the individuals of each pair being precisely similar in form and magnitude, and having corresponding positions to the right and to the left of the median plane. The single muscles, which alone are exceptions to this, are so formed and placed that they are divided symmetrically into two halves, precisely similar to each other, by the median plane.

120. We have hitherto regarded the muscles merely as agents by which bones are moved ; their power is, however, equally extended to the softer parts of the system, on which their play is not less important than on the members of the skeleton. In the face, for example, where the play of the features is so varied and expressive, the only movable bone is that of the under-jaw ; and, consequently, with that exception, all the motions produced by the facial muscles are imparted to the softer parts.

The involuntary muscles, generally, are inserted in the softer parts of the organs.

121. When the vast number of the muscles, and the great magnitude which must be given to many of them to confer on them the force necessary for the actions respectively assigned to them, are compared with the superficial extent of the regions they occupy, it will doubtless excite surprise how the space has been found requisite for a dynamical apparatus so complicated ; and although many, including all the involuntary muscles, are placed in the internal cavities of the trunk, the number which still remain to be located upon the external parts of the skeleton is far more considerable than would be sufficient to cover it.

It has been so ordered, however, that the parts of the body in which the motions are most numerous are precisely those where least resistance is presented to the moving power ; and, consequently, although the muscles in such regions are proportionally greater in number, they are smaller in magnitude, and therefore, collectively, occupy less surface. The face presents a remarkable illustration of this.

On the contrary, those regions where the greatest resistance is opposed to the motions, and where therefore the muscles must be strong and large, present a much more extensive surface for their establishment. The trunk is a striking example of this.

122. But even this relation, which is maintained between the superficial extent of the several parts of the body, and the magnitude of the muscles with which they are invested, is not sufficient to allow these organs to be distributed superficially. They are therefore, everywhere, as well on the trunk as around the members, superposed in layers, the number of which is determined according to the proportion which the number and magnitude of the muscles bears to the superficial extent of the parts over which they are distributed. The number of layers varies in different regions of the body from one to six.

123. When the complication of this system of mechanical agents is considered, and when it is known that not only each particular muscle is subject to the immediate command of the will, but that, in many cases, different sets of fibres of the same muscle may be called into action at its dictates, separately or successively, and that to produce a single motion the combined action of many muscles is often required, the intensity of such forces being so nicely proportioned one to another that the force to be imparted to the member which they move shall be the exact mechanical resultant which such components would have according to the geometrical principles upon which the theory of the composition of force is based,—the promptitude with which springs so various receive and execute the dictates of the will cannot fail to excite the most profound sense of wonder and admiration. It is impossible to contemplate the performance of such mechanism, and the continuance of its action, without other derangement than such as may arise from external accidents during the life of the individual, without being impressed with a lively sense of the infinite inferiority of all artificial contrivances of human invention.

124. The face is the theatre of motions infinitely varied, which, though they include the play of the most important organs, are produced with the smallest amount of mechanical force. The tegumentary covering of the forehead and skull, the eyes, eyebrows, and eyelids, the nose and nostrils, the cheeks and temporal integuments, the lips, tongue, and chin, are severally susceptible of motions which give expression to the endless variety of sentiments, passions, and mental emotions, and which in each individual have characters so peculiar as to afford means of his immediate identification, and to distinguish him from all others of his kind. That such complicated mechanical effects should require an equally complicated system of moving powers, will excite no surprise; and we find,

accordingly, that an apparatus consisting of about seventy pairs of muscles, spread over the head, face, and neck, is appropriated to this purpose. So far as they can be rendered superficially visible by the removal of the skin and integuments, they are shown in fig. 53.

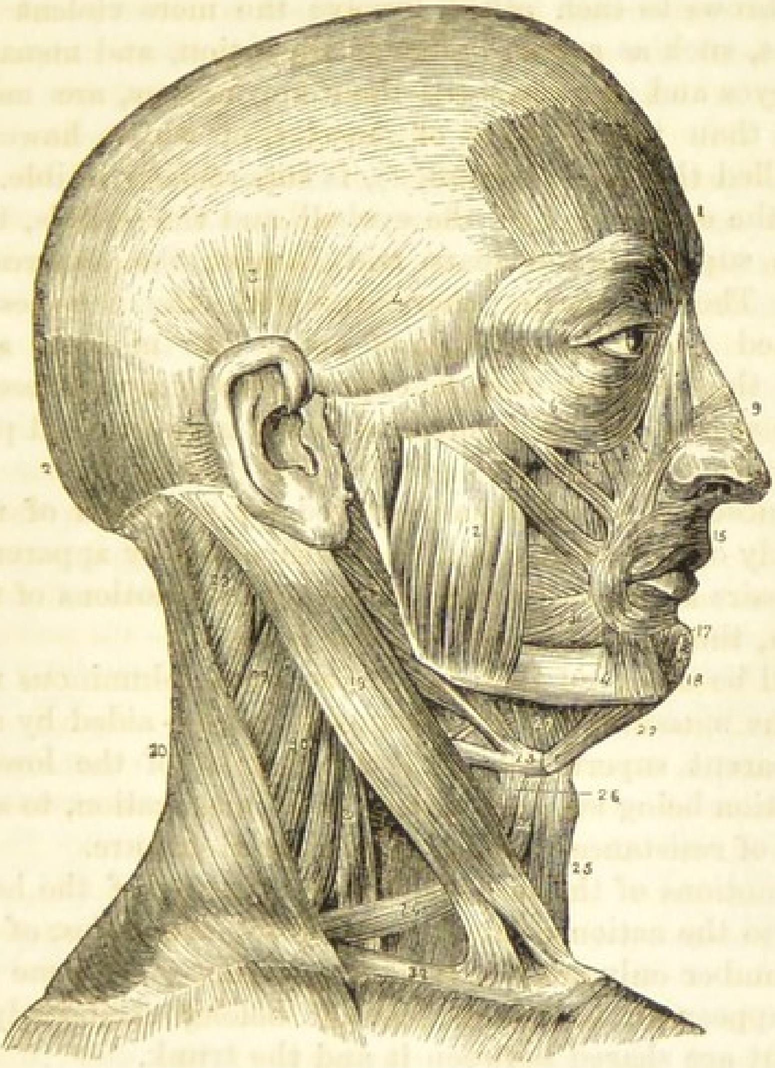


Fig. 53.

A stratum consisting of five or six muscles (53, [1], [2], [3], [4], [5]) of considerable surface, but little thickness, covers the entire surface of the head from the brows to the back of the neck, called by anatomists, according to their local position, *occipital*, *frontal*, and *auricular*, the action of which is to move the scalp, with the hair, the ears, the integuments of the forehead and temples, and the brows. By their contraction, the eyebrows are drawn upwards, the skin of the forehead thrown into transverse folds and wrinkles, the scalp and hair moved back-

wards and forwards, and the features thereby made to express various and often opposite emotions, according to the greater or less extent to which the action of these muscles is called into play. Joy, surprise, astonishment, or ecstacy, are attended with, or expressed by, a certain elevation of the brows. The contractions and wrinkling of the forehead and the approach of the brows to each other, involve the more violent class of emotions, such as anger, hatred, indignation, and menace.

The eyes and eyelids, with their appendages, are moved by not less than twelve pairs of muscles, of which, however, one only, called the orbicular (53, [6]), is superficially visible. These govern the entire play of the eyeball and the eyelids, the flow and the suppression of tears, and, in part, the gestures of the brows. They combine, therefore, with the muscles above mentioned in the expression of anger and menace, and also assume the gestures which express the very different and opposite sentiments of tenderness, love, grief, mental pleasure, and anguish.

The nose and nostrils are moved by six pairs of muscles, three only of which (53, [7], [8], [9]) are superficially apparent; and fifteen pairs are appropriated to the various motions of the lips, the chin, the cheeks, and the lower jaw.

It will be observed that one of the most voluminous muscles, called the *masseters* (53, [12]), is appropriated—aided by another, not apparent superficially—to the motion of the lower jaw; that motion being subject, in the act of mastication, to a greater amount of resistance than any other facial gesture.

The motions of the neck, and consequently of the head, are subject to the action of about forty pairs of muscles, of which a small number only are superficially visible. And some of those which appear in the figure do not belong exclusively to the neck, but are shared between it and the trunk.

Eight pair of muscles are more or less called into play to make the head incline forwards, among which is the long muscle (53, [19]) extending from the ear to the point where the clavicle (53, [32]) is articulated with the sternum, or breast-bone; another, called the mylo-hyoidean, extending downwards from the jaw; and another, the digastric (53, [21], [22]), extending from the inner extremity of the jaw on one side, and its outer extremity on the other, to the hyoid bone (53, [23]).

Seven pair of muscles are employed, together or separately, in inclining the head backwards, among which there appear in the figure the trapezius (53, [20]) and the splenius (53, [28]). Seven

pair are engaged in inclining the head sidewards, several of which are also those, such as 53, [19] and 53, [20], which incline the head backwards.

125. The trunk is surrounded by about a hundred pair of muscles, which are superposed in six layers upon the back, but less crowded in front ; a circumstance which will be easily understood when it is remembered that the centre of gravity of the trunk, being placed in front of the vertebral column, must necessarily be supported by the reaction of powerful muscles posterior to it.

126. Owing to this thick superposition of so many layers on the back, it is difficult to present by diagrams any distinct representation of the muscular structure of that region. Some notion of it, nevertheless, may be conveyed by exhibiting successively one layer after another.

In fig. 54 the superficial muscles of the back, including the neck, shoulder, and haunch, are shown on the left side of the spine ; and those of the second layer, disclosed by the removal of the former, on the right side.

It will be seen that the superficial muscles are few in number, and great in magnitude. Those of the back, properly so called, being only two ; the trapezius extending from the neck (A) to the spine of the scapula and clavicle (54, [3], [4]) and downwards along the spine at 54, [13]. The other, called the great dorsal (latissimus dorsi), (54, [9], [10]) covers the remainder of the back and side, and extends upwards towards the arm-pit. A large angular-shaped muscle (54, [5]), extending from the clavicle and the spine of the scapula (54, [3], [4]) over the upper extremity of the arm, is called the *deltoid* from the resemblance of its outline to the Greek letter delta, Δ, and another large muscle (54, [11]) covering the haunch is called the *gluteus maximus*. The muscular stratum beneath this is exposed on the right side of the figure, where the principal muscle in the dorsal region is the serrated or dentelated muscle (54, [10]. [22]).

The action of the superficial dorsal muscles influences several motions of the body, and varies according as one part or another of their attachments become fixed by the dictate of the will. Thus, if the shoulders be held fixed, and both the trapezian muscles be contracted, the head will be drawn backwards ; but if one be contracted and the other relaxed, it will be inclined to the side of that which is contracted. If, on the other hand, the head be fixed, these muscles act together or separately in elevating both or either of the shoulders, in which operation they are sometimes aided by the great serrated muscle (54, [19]).

The great dorsal muscle, when it acts on the upper bone of the arm, draws it downwards ; and if the shoulder and arm be

fixed, it reacts upon the ribs, and elevates them. Both these dorsal muscles occasionally react upon the spine, when the shoulder and arm become relatively fixed. Thus, if a man

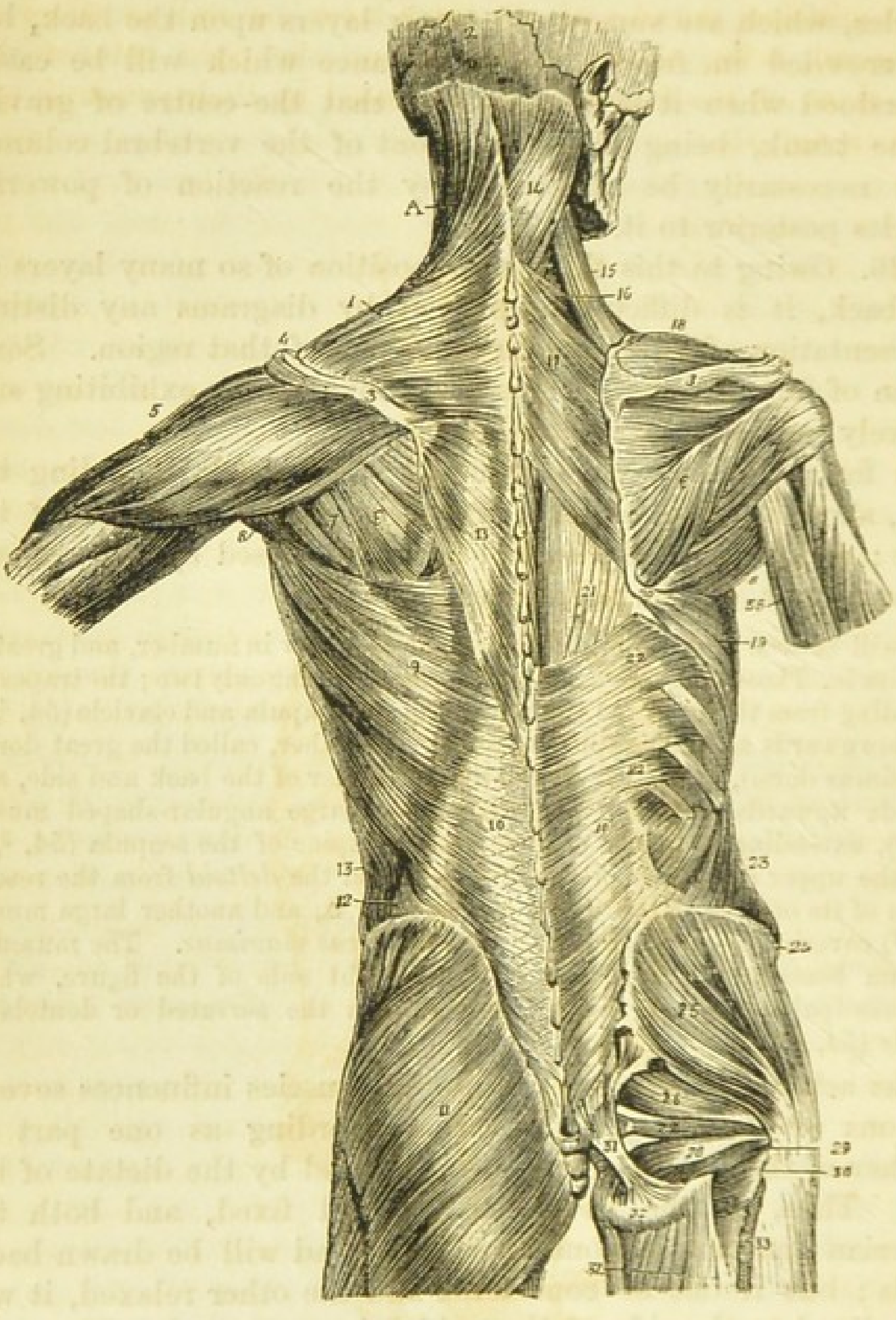


Fig. 54.

walking on the edge of a raised footpath happens to incline a little on the outside, by a violent exertion of the muscles just mentioned, the spine is drawn to the opposite side, and stability restored. Exhibitors on the tight-rope have these great superficial muscles of the back in constant play, these being

the principal means of redressing their balance, and, by their alternate contraction and relaxation, causing the centre of gravity of the body to oscillate slightly to the right and left of a vertical plane, through the centre of the rope.

The principal muscles of the third layer, as well as those of the second, being shown in fig. 54, on the right side of the spine, those of the fourth layer, disclosed by their removal, are shown in fig. 55.

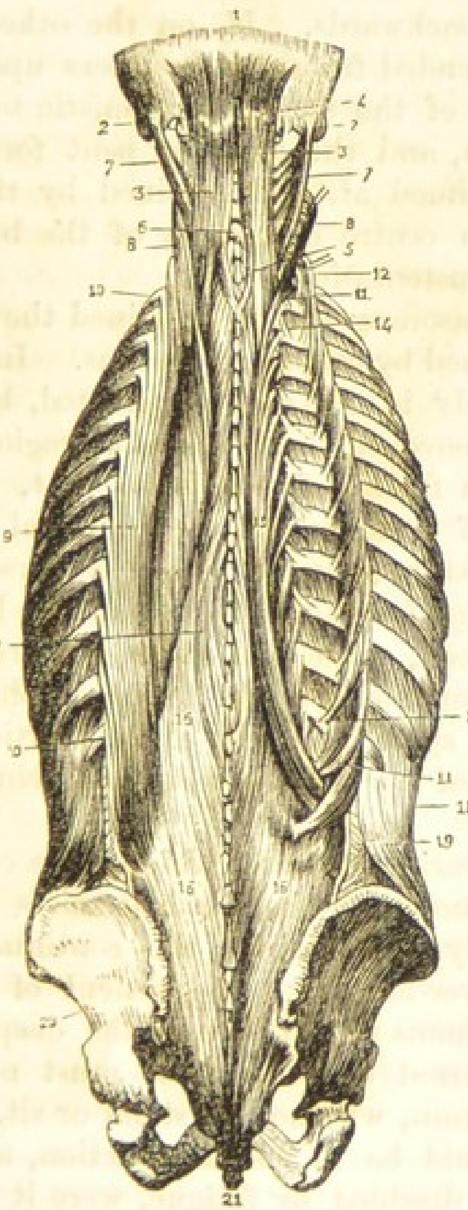


Fig. 55.

The muscles of these deeper layers act chiefly upon the trunk, their tension equilibrating with the weight of the body, which tends to bend the spinal column forward. Most of them are

attached to the spinous and transverse processes of the dorsal and lumbar vertebræ. They maintain the trunk erect, whether we are stationary or in motion. If their contraction be extreme, the spinal column will be bent somewhat backwards; which always happens when the natural weight of the trunk in front of the spine is augmented by a weight suspended in front from the neck. Thus, it may be observed, that when a hawker carries a basket or tray before him, supported by a strap passing round his neck, he assumes an attitude in which the vertebral column is bent backwards. If, on the other hand, a porter carry a load suspended from the shoulders upon the back, the muscles in front of the spine, antagonistic to the former, are called into action, and the spine is bent forwards. In such case the object aimed at, and attained by the gesture, is to bring the common centre of gravity of the body and its load over the base of sustentation.

By the same reasoning will be explained the peculiar attitude of the body assumed by corpulent persons. In such a state the weight of the body is not only augmented, but, owing to the increased prominence of the abdominal region, the centre of gravity is thrown farther forwards, so that, to bring it back within the base of sustentation, the vertebral column must be bent more or less backwards. Such a person would find it difficult, or perhaps impracticable, to carry a load suspended in front from the neck, while one suspended from the shoulders upon the back would tend rather to relieve the dorsal muscles, by allowing the spine to assume the vertical position, the centre of gravity of the body and its load being within the base of sustentation.

By providing various muscles which have certain mechanical functions in common, or are, as anatomists say, congenerate, Nature has wisely provided for the continuance of muscular action without over-fatigue. The benefit of this provision is especially conspicuous in the play of the deeper class of dorsal muscles now referred to. As these must necessarily support the vertebral column, whether we stand or sit, are in motion or at rest, they would be in constant action, and would consequently soon be disabled by fatigue, were it not that congenerate muscles, and even different parts of the same muscle, relieve each other. Thus, for example, the lower fibres of the spinal muscles, which pass from the sacrum to the processes of the lumbar vertebræ, aid the other muscles in the support of the column, by rendering the transverse processes to which

they are attached so many fixed points, from which the succeeding parts of the spinal muscles transmit their effects through the entire height of the column, by a succession of efforts propagated upwards, with a sort of vermicular motion. When by this means the action of one set of fibres succeeds that of another, each will have its alternate intervals of contraction and relaxation, as well as the fibres of other muscles, in which this state of intermission is more manifest. The muscle called the *sacro-lumbalis* can draw down the lower ribs; and, if the effort be continued, this influence must soon be propagated to the vertebral column, which is thus bent towards the side by means of the intimate connection between the heads of the ribs and the vertebræ. The lower fibres of the spinal muscles will produce the same effect, so that the action of these may in like manner be interchanged and intermitted.

The spine admits, to some extent, of a motion of rotation, or, more properly, of a limited angular motion round its longitudinal and vertical axis. Thus, the head may be turned round horizontally, until the face looks over either shoulder, after which the vertebral column may be made to turn upon its own axis, until the face shall have completed almost a semicircle from the point at which its motion began, the pelvis and legs remaining, meanwhile, unmoved. The latter movement is effected by that peculiar action of the spinal muscles above referred to. But it is the muscle of the side opposite to that towards which the motion takes place which produces the rotation.*

127. The principal anterior muscles of the trunk and shoulders are shown in fig. 56, those on the left being superficial, and those on the right the deeper layer covered by the former. In proportion to the surface over which they are spread, these muscles are much less numerous than those of the back, a circumstance which naturally arises from the fact already indicated, that the weight of the trunk being chiefly in front of the spine, is altogether supported, and, for the most part, moved by the posterior muscles shown in fig. 54.

The anterior muscles shown in fig. 56, though located upon the trunk, act, for the most part, in moving the arms and shoulders. The superficial ones on the left side of fig. 56 are few in number, and great in extent. The great pectoral muscle (56, [2], [3]) has its origin along the edge of the breast-bone (56, [1]), and along something less than half the length of the clavicle (56, [6]) and from these lines the fibres converge to a point a little below the

* Quain's Anatomy, 5th Edition, p. 513.

head of the humerus, and on the inside part of that bone. The clavicular fibres of this muscle, therefore, draw the arm obliquely upwards and inwards, having a tendency to secure the head of the bone in its socket; while the sternal fibres, being nearly horizontal, draw it inwards towards the side.

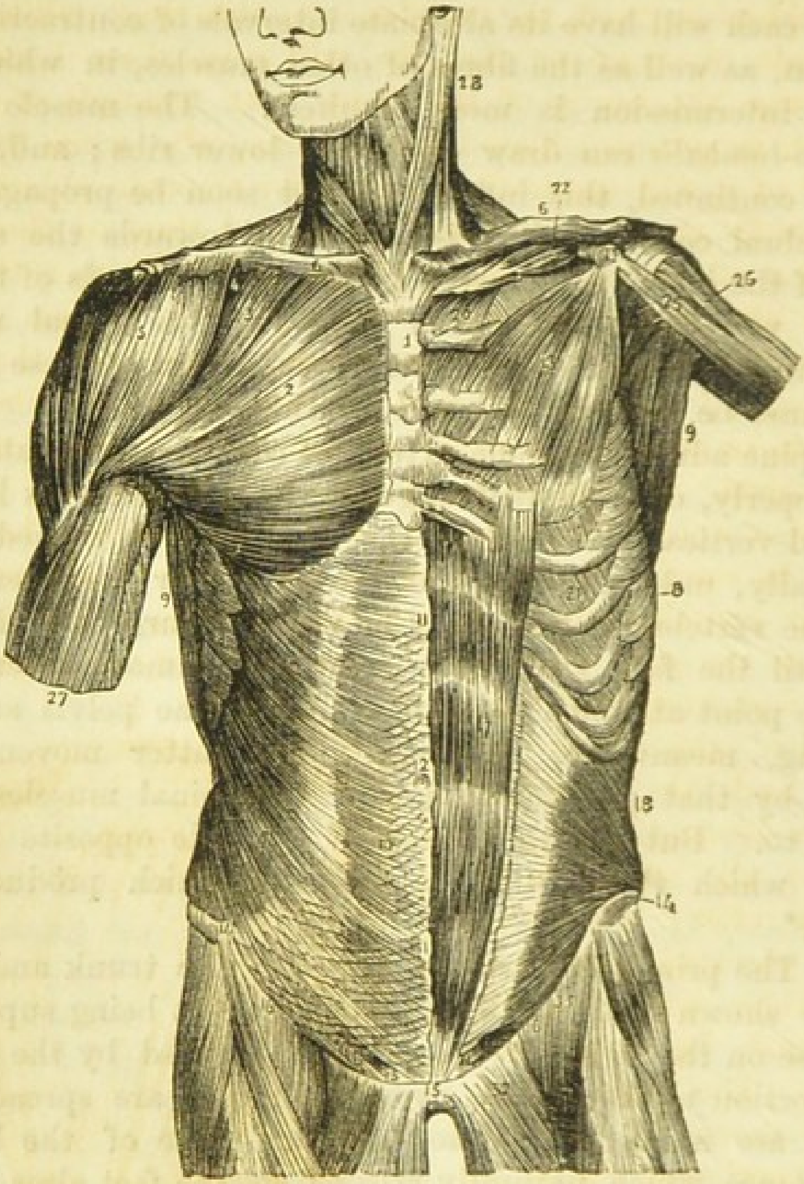


Fig. 56.

The lesser pectoral muscle, which is covered by the greater, is shown at 56, [13]. It is attached at its origin to three of the ribs,—the third, fourth, and fifth, and at its insertion to a process (the coracoid) of the scapula.

The dentelated insertion of the great serrated muscle already described, attached to the ribs, is shown at 56, [8]. The front part of the deltoid, already mentioned, is also shown at 56, [5].

128. **Brachial Muscles.**—The power of the great pectoral, 56, [2] and [3], upon the motions of the arm are considerable. Besides depressing the humerus, and drawing it into close contact with the side, its lower fibres will trail the arm along

the side and front of the chest. The lesser pectoral, 56, [13], draws the point of the shoulder downwards and inwards towards the thorax ; but the action of both of these muscles may be entirely changed if the points of their insertion be fixed. Those of their origin will then become movable ; thus, if the arms and shoulders be fixed, the muscles in contracting, pulling upon their points of origin on the ribs, will raise these bones, and thus enlarge the cavity of the chest. An example of this is often seen in persons afflicted with asthma, who, when they feel the want of a full inspiration, seize hold of some object, so as forcibly to fix the shoulders and arms, and thus to throw the whole force of the pair of lesser pectorals, 56, [13], upon the ribs.

When the shoulder-blade is fixed by the tension of the trapezius and rhomboid muscles already described, the great serrated, 56, [8], having its force thrown upon the ribs, acts upon them in the same manner as the lesser pectoral muscles just described. In this effort the shoulder is elevated, just as if a burden were sustained upon it. This exertion, however, can only be continued so long as the chest is kept inflated ; for if the air contained in it be permitted to escape, the external pressure of the atmosphere will be too great for the force of the muscles, and, in spite of their contraction, the chest will collapse and the ribs and shoulders descend.

Fig. 57.

During all muscular efforts, therefore, which require an elevated position of the shoulder and ribs, the chest must be kept well inflated. The necessity for this was shown by an ingenious experiment made by M. Bourdon. He opened the trachea or larynx of a dog that had been in the habit of jumping and tumbling at command, after which all the attempts of the animal to make such evolutions were unavailing, —the air which had been inspired into the chest escaping through the aperture thus artificially made. But when the

operator, by uniting the margins of the wound, closed the aperture, the lost power was instantly restored.*

The deltoid muscle, half shown in figs. 54 and 56, and more fully exhibited in fig. 57, is one of the most important parts of the mechanism of the arm. Its origin is extended over about a third (57, [2]) of the clavicle to near the point where that bone articulates with the scapula, and also along the spine of that bone (57, [5]). The fibres converge from this line to a point (57, [6]) upon the humerus at some distance below its head; and since, according to what has been explained generally, the will has the power of directing its mandates to the fibres, either collectively or separately, it can impart very different motions to the arm, according as the contraction is limited to the internal and clavicular fibres, or to the external or scapular, or, in fine, imparted simultaneously to all.

It must be observed that the mechanical power exerted by the fibres of this muscle upon the arm is greatly augmented by their being carried over the head of the bone.

The humerus is also connected with the shoulder and some other im-

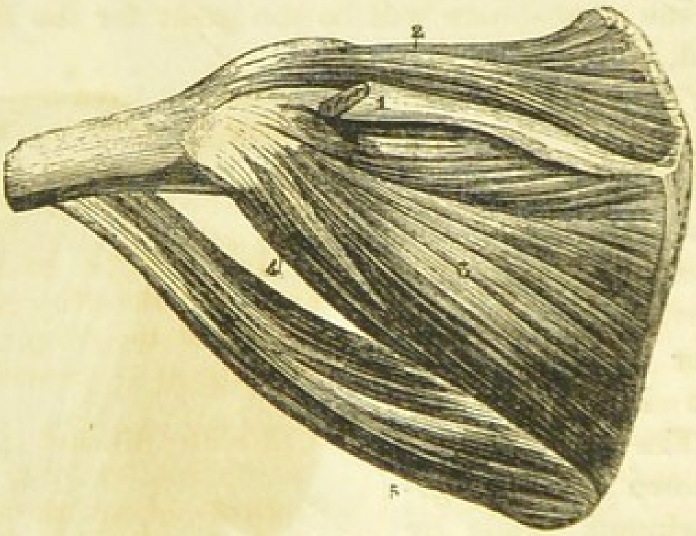


Fig. 58.

portant muscles, which are imperfectly seen in figs. 54 and 56, but more clearly visible in fig. 58.

From the point where the humerus is articulated with the scapula, a ridge of bone (58, [1]) called the spine of the scapula runs horizontally, and two muscles called, from their position, the *supra-* and *infra-spinatus* muscles (58, [2] and [3]), connect the humerus at points somewhat beyond its head with the inner edge of the scapula. Two other muscles (58, [4] and [5]), called the *teres minor* and *major*, or lesser and greater round muscles, connect the scapula also with the humerus at points a little lower.

* Bourdon, Mémoires sur les Efforts, quoted by Quain.

The action of this set of muscles upon the arm is very various and important. By the collective action of all its fibres, the deltoid (fig. 57,[1]) can raise the arm directly from the side, so as to extend it horizontally at right angles to the body. It can then be alternately directed forwards or backwards by the contraction and relaxation of the anterior and posterior fibres of the muscle, assisted, however, in the one case by the lower fibres of the great pectoral 56,[2], and in the other by the teres major, 58,[5]. The force of the deltoid, owing to the mass of its fibres, is so great, that by a further contraction it can make the head of the humerus glide upon the cavity of the scapula so as to direct the arm vertically upwards. In this operation the supra-spinatus muscle, 58,[2], plays an important part; for, owing to the extremely shallow cavity in which the head of the humerus is articulated, there would be great danger of dislocation by such a vertical movement of the arm as that here described. This is, however, prevented by the supra-spinatus, which, contracting with great force at the moment of the elevation of the arm, retains the head of the humerus in its place, and discharges for the moment the functions of a ligament.

The muscles represented in fig. 58, except the teres major 58,[5], are capable of rotating the arm externally; their power being, like that of the deltoid, increased by passing over the head of the humerus, and also by being attached to processes of that bone, which gives them a certain leverage upon it.

The teres major, 58,[5], depresses the arm if it be raised, and also rotates it on its axis. If the arm be fixed, and the elbow removed from the side, this muscle, assisted by another called the *triceps*, which will presently be described, can draw the lower edge of the scapula, and with it the whole trunk, towards the arm.

A front view of the humerus and left shoulder, divested of the deltoid muscle, is shown in fig. 59.

The teres major, already described, is shown at 59,[5], and the muscle called the *sub-scapular*, having its origin extended vertically along the surface of the scapula and its insertion upon the humerus a little below the head, is shown at 59,[4].

129. The muscles which extend along the front of the humerus from the shoulder to the elbow, and have their insertion below the elbow on the bones of the fore-arm, appear also in fig. 59. The corresponding muscles on the back of the same bone,—the tendons of which, extending over the elbow, are inserted in the back of the fore-arm,—are shown in fig. 60.

The principal muscle in front, called the *biceps* from having two origins,

appears at 59,[7]. Its origins, as indicated in the figure, are at two points not far removed from each other upon the scapula ; and its tendon, commencing a little above the hollow of the arm, passes under the muscles of the fore-arm, and is inserted in a small process issuing from the radius.

Immediately within the upper part of this biceps muscle is one called the *brachialis anticus*, or internal brachial muscle, 59,[9], which extends along the lower half of the arm, being covered by the biceps. Its origin is in the front of the humerus below the deltoid ; and, passing before the bend of the elbow, it is inserted in a process of the ulna. Thus, it appears that while the biceps acts upon the radius, the internal brachial controls the ulna.

Only one muscle, called the *triceps cubiti*, fig. 60, [1], [2], [3], lies upon the back of the humerus. As its name implies, it has three heads or origins. The first, the long part, 60,[2], is attached to the border of the scapula immediately below the cavity of the shoulder-joint. The second, the external part, 60,[1], is attached to the external and upper surface of the humerus ; and its internal part, 60,[3], to the posterior surface of the upper part of the humerus. The lower extremity of this muscle is attached to

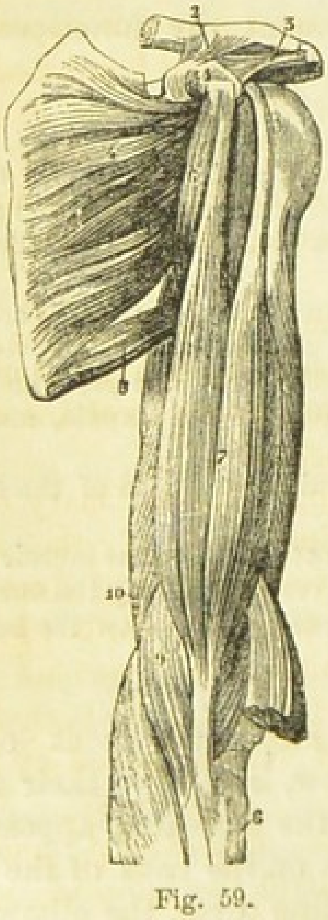


Fig. 59.

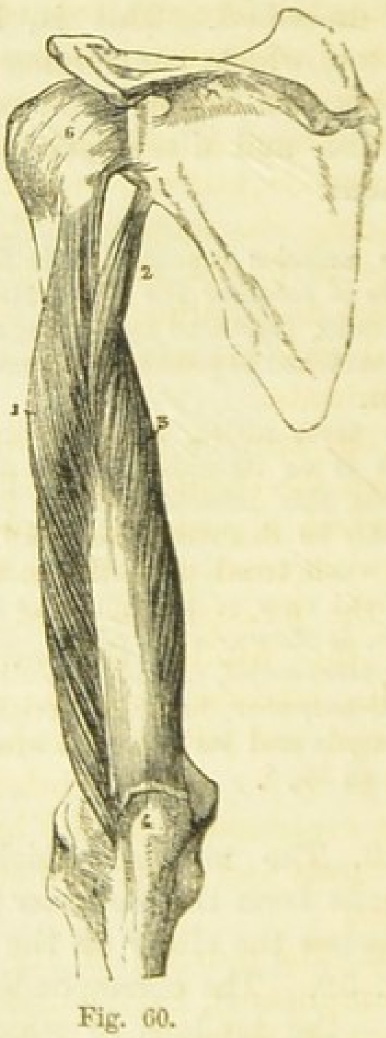


Fig. 60.

the part, 60,[4], of the ulna called the *olecranon*, which, projecting from its upper end, forms the point of the elbow.

When the origins and insertions of these several muscles are attended to, their mechanical action will be very apparent. The shoulder and humerus being fixed, the biceps 59,[7], and the brachialis anticus 59,[9] acting upon the points of the radius and ulna already described, draw them forwards, so as to incline the fore-arm at an angle with the humerus. These are, therefore, the *flexor* muscles of the fore-arm. On the other hand, the triceps 60,[1], 60,[2], 60,[3], acting on the projecting bone of the elbow 60,[4], which is part of the ulna, has a tendency to straighten the arm, if inclined, and is, therefore, the immediate antagonist of the former.

The flexor muscles are more numerous and much more voluminous than the triceps or extensor, and a greater leverage is moreover given to them, by being inserted at lower points, and with longer processes, on the two bones of the fore-arm. This arrangement is in obvious accordance with the mechanical exigencies of the member. When we use the arm to raise a weight or overcome a resistance, the object is attained always by inclining the fore-arm towards the shoulder; and, even when no weight or resistance is opposed to the flexion, the weight of the fore-arm and the hand must be overcome. But whenever the arm is extended, not only is no force or resistance opposed to its extension, but the weight of the fore-arm and hand assists in producing the motion. Thus we find that a single extensor muscle is placed at the back of the arm with a very small leverage to produce this effect, the small leverage being attended with the advantage of straightening the arm with great promptitude.

If the arm be felt, it will be found that the fleshy mass between the shoulder and elbow, in front, is much greater than that which is posterior, showing the much greater volume of the flexor compared with the extensor muscles.

If the fore-arm be fixed by grasping any stationary object with the hands, the origin and insertion of the flexor muscles interchanging characters, their action will draw the humerus, and with it the shoulder and trunk, towards the fore-arm, as is so often exhibited in climbing and various gymnastic evolutions. If the humerus and fore-arm be both fixed, the scapula and parts connected with it will be moved by these muscles.

130. The muscles of the fore-arm are necessarily numerous and complicated, having under their control the infinitely varied motions of the hand upon the wrist, a considerable share in those of the fingers, and, in certain cases, producing the flexion and extension of the fore-arm on the elbow-joint, in which case

they co-operate with the corresponding muscles of the humerus. When, however, it is considered how large a share must be assigned to the hand in the superiority which man possesses over all other animals, including even those which immeasurably exceed him in strength and swiftness, it must be admitted that its mechanism is deserving of more than common attention, even in the briefest sketch of animal physics.

The bones of the fore-arm are surrounded by nineteen muscles; the bodies or *bellies*, as they are technically called, of which, being placed chiefly in the upper-half, give that peculiar tapering or fusiform shape to this part of the limb with which every eye is familiar, and which, when regular, as in the female arm, confers great beauty on the member. These muscles terminate above in single tendons, which are attached either to the humerus, a little above the elbow, or to one or other of the bones of the fore-arm, a little below it; but chiefly to the former, with which thirteen of them are connected. The bellies of these muscles being situated as just explained, round the upper part of the arm, the tendons which connect them with their origin are short; but since the muscles, properly so called, terminate at a considerable distance above the wrist, their lower tendons, all of which descend to the wrist and many to the hand and fingers, are very long. This multitude of tendons, surrounding the wrist especially on the side of the palm of the hand, can be distinctly felt, there being no other fleshy matter at that part.

Of these thirteen muscles, eight are placed in front of the arm, between the wrist and the bend of the elbow; three are placed on the external border of the arm, between the thumb and the external corner of the elbow-joint; and the remainder lie upon the back of the arm, between the back of the hand and the elbow. Those which lie on the front of the arm are the strongest and most voluminous, and give to the member the fleshy form found in that place.

It will be remembered that in the normal position of the arm, supposing it to be held with the palm of the hand presented forwards, the two bones of the fore-arm, called the radius and ulna, lie parallel to each other; the radius being in the line of the thumb, and therefore outwards; and the ulna in that of the little finger, and therefore inwards. It has been also shown, that the structure of the joints is such, that the lower end of the radius has the faculty of revolving round that of the ulna, and the hand, being attached to it, must participate

in this revolution. In this change of position, the radius ceases to be parallel to the ulna, and forms an angle with it, which continually increases until the palm of the hand is presented backwards; in which case, the lower end of the radius will have made half a revolution round the ulna.

Of the two extreme positions of the hand, here described, that in which the palm is presented forwards, the radius being then in its natural position parallel to the ulna, is called the position of *supination*; and that in which the palm is presented backwards, the radius being oblique to the ulna, is called the position of *pronation*. The muscles which move the radius round the ulna, so as to give the latter

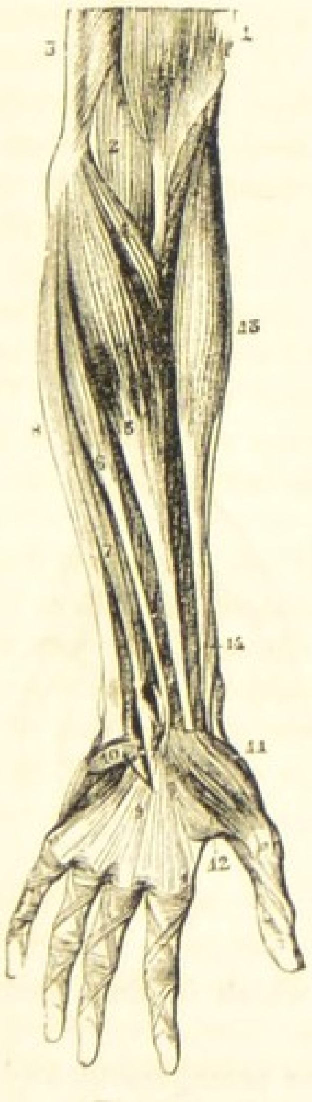


Fig. 61.

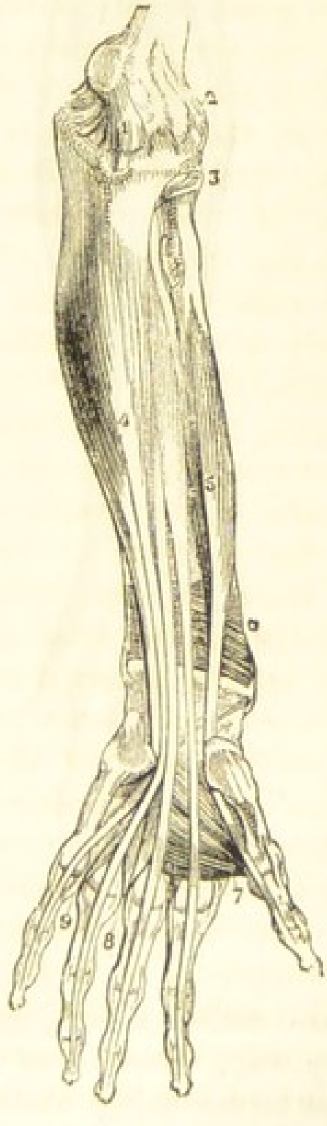


Fig. 62.

position, are accordingly called *pronators*; those, which move it back to the hand, its natural position, being called *supinators*.

The muscles which bend the hand upon the wrist, so as to place the palm at an oblique or right angle, with the front of the fore-arm, are called *flexors*, and those which bend the hand backwards, so as to incline the back of the hand similarly to the back of the arm, *extensors of the wrist.* In like manner, the muscles which bend the fingers and thumb towards the

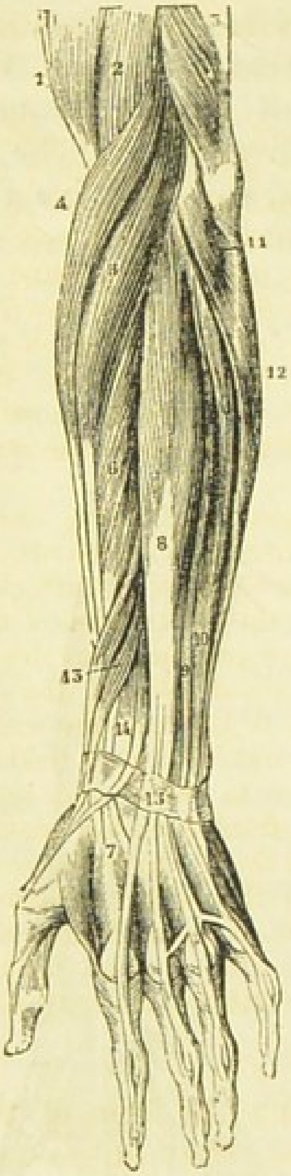


Fig. 63.

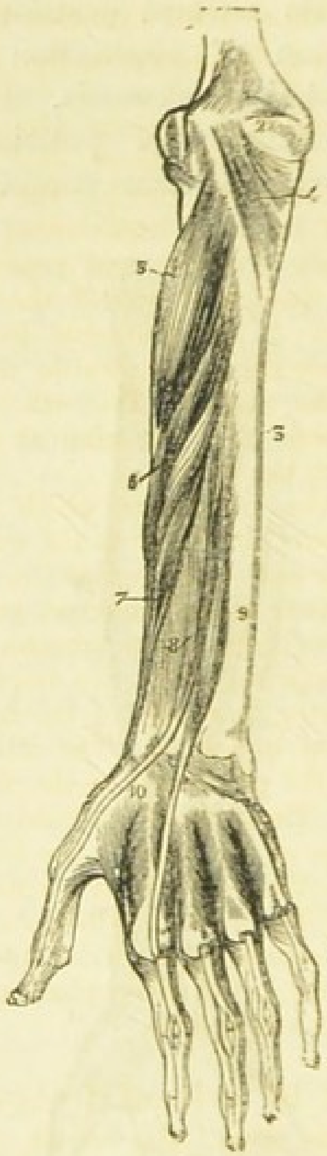


Fig. 64.

palm are called *flexors,* and those which incline them in the contrary way, *extensors of the fingers.*

These terms being understood, the arrangement and play of the muscles will be easily comprehended.

A front view of the left arm and hand, the palm of the hand being supposed to be turned to the observer, and the thumb, therefore being outwards, and the little finger inwards, is

shown in fig. 61; where, however, the superficial muscles only are seen.

A similar view of the same arm, with the superficial muscles removed, so as to disclose the deeper ones, is shown in fig. 62.

A posterior view of the same arm, with the back of the hand presented to the observer, the superficial muscles only being visible, is shown in fig. 63; and a similar view of the same arm, the superficial muscles being removed, so as to disclose the deeper ones, is shown in fig. 64.

Of the nineteen muscles above mentioned, two 61,[4], and 62,[6], are pronators; and two others 61,[13], and 64,[5], are supinators; the former by their contraction turning the radius round the ulna, so as to present the palm of the hand backwards; and the others drawing back the radius to its former position, and presenting the palm of the hand forwards. The upper tendon of one of the pronators 61,[4], is implanted upon the inner corner of the humerus immediately above the elbow; and the muscle, proceeding downwards diagonally, is inserted into the middle third of the radius. The other pronator is a much shorter muscle, passing across from the ulna at a little distance above the wrist to the radius above the thumb.

Of the two supinators which are antagonists of these, one 61,[13], is attached above the elbow to the external corner of the humerus, and below to the lower end of the radius; and the other 64,[5], is also attached to the external corner of the humerus, and goes to the upper third of the radius.

Of the remainder of the muscles of the fore-arm, six send down tendons which, passing the wrist, are implanted in one or other of the metacarpal bones, forming that part of the hand which is between the wrist and the upper row of knuckles. The others throw out divergent tendons, which descend to the phalanges of the fingers, some to the second, and some to the third. Those which proceed from the front muscles, passing to the palmar sides of the fingers, are flexors; and those which proceed from the muscles on the back of the arm, going to the back of the fingers, are extensors. The muscles which lie along the external border of the arm, send their tendons to the wrist and thumb. One of these, inserted in the radius, is the principal supinator, and the others are extensor muscles of the wrist and thumb.

It will be evident from considering the form of the lower part of the arm, the wrist, and hand, that unless some provision were made to the contrary, the force of the brachial muscles, transmitted along their tendons to the various parts of the hand in which they are severally inserted, would necessarily cause the tendons, whether on the back or front of the wrist, to separate from it when the hand is inclined to the arm, and to take the direction of the base of a triangle of which the hand would be one side, and the arm the other. In assuming this position, they would obviously force the integument of the wrist outwards from its natural position. It is obvious

that since this does not happen, some adequate mechanical provision against it must be supplied in the mechanism of the wrist. Such an expedient is in fact found in two semicircular ligaments, which surround the wrist outside the tendons, one above the palm, and the other above the back of the hand; the former being called the *anterior*, and the latter the *posterior annular ligament.* The latter is shown at 63,[15], the former being removed in fig. 61, for the purpose of showing more clearly the course of the tendons.

These two ligaments, therefore, form a powerful bracelet, by which the numerous tendons running from the brachial muscles to the hand are bound to the wrist, whatever position the hand may assume. When the hand hangs in its natural position in the direction of the arm, the tendons produce no pressure on the annular ligaments ; but when the hand is bent inwards, the palmar tendons form an angle at the anterior ligament, which holds them down ; and when, on the contrary, the hand is inclined backwards, the posterior tendons form a like angle at the posterior ligament, by which they are held down.

Synovial membranes are provided for the lubrication not only of these annular ligaments, but of all the grooves and surfaces along which the numerous tendons sent by the brachial muscles to the hand and fingers pass, so as to give the parts the utmost freedom of motion.

The circumstance already mentioned, that not fewer than thirteen of the nineteen lower brachial muscles have their origin in the humerus above the elbow, will readily suggest the influence which these must have in certain cases, as flexor and extensor muscles of the fore-arm. When, for example, by the force of the muscles placed on the anterior surface, the hand is bent inwards as far as it can go towards the front of the arm, any further contraction of the anterior brachial muscles must inflect the fore-arm on the humerus ; for the hand no longer yielding to their action, the insertions of the tendons in the bones of the hand become fixed points, and the anterior annular ligament becomes a fixed pulley, by which the muscular reaction is directed upon the points where the upper tendons of the muscles are implanted in the humerus above the elbow. It is evident that, in this case, the contractile force of the muscles draws the annular ligament towards their points of insertion in the humerus ; and since these points are above the elbow, the fore-arm will be bent, with more or less force, towards the humerus, and its muscles will thus become, for the moment,

congenerate with the ordinary flexor muscles which lie upon the humerus.

131. **The Hand.**—Besides the motion imparted to the hand by the brachial muscles, above described, there is another system of muscles established on the palm of the hand, which are more especially appropriated to the motion of the thumb and fingers. Four of these, the bellies of which form what is called *the ball*, are appropriated to the motions of the thumb. Four others, which form the thick fleshy mass on the inner border of the hand, are appropriated to the motions of the little finger, over which they are placed.

The chief part of the muscles which move the other fingers, are the brachial muscles, already described, whose tendons proceed from the fore-arm to the hand. There are, however, interosseous muscles which lie between the metacarpal bones, the action of which is to open and close the fingers, and which also have some slight effect in inflecting them upon the palm of the hand.

The superficial muscles of the palm of the left hand are

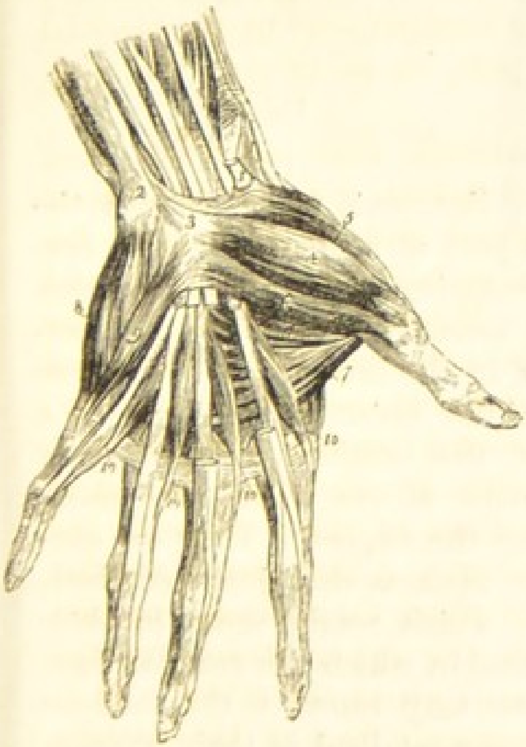


Fig. 65.

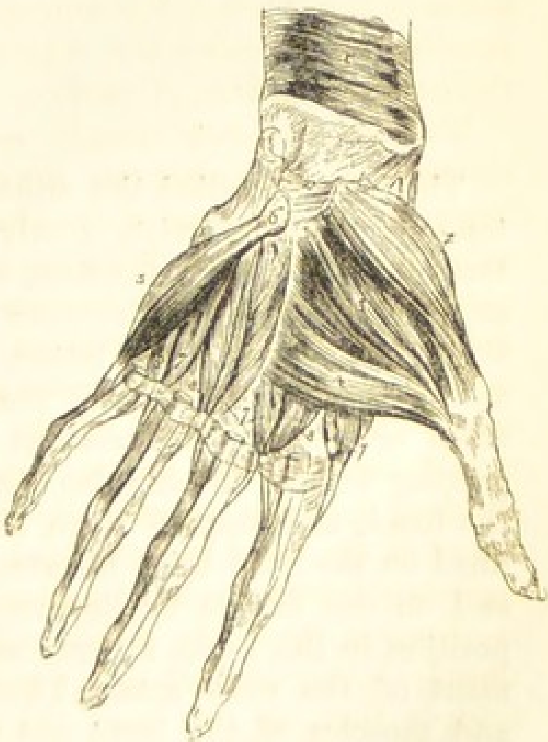


Fig. 66.

shown in fig. 65, and the deeper ones, disclosed by the removal of the former, in fig. 66.

The dorsal interosseous muscles of the right hand, and their connections with the tendons of the long extensor muscles of the fingers, are shown in fig. 67, and the palmar, with their connections, in fig. 68.

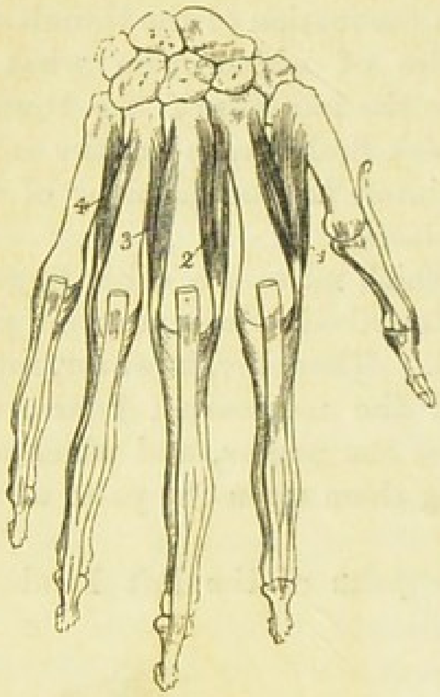


Fig. 67.

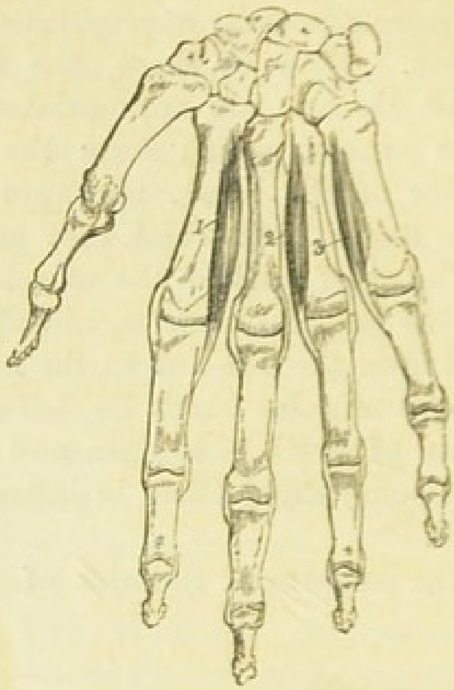


Fig. 68.

The bracelet called the annular ligament, which retains the tendons upon the wrist, is only a part of a more extensive system of membranous binding, enveloping generally the muscles and their tendons. Wherever a considerable change of direction takes place in the latter, as in the instance of the elbow and wrist, this membrane sometimes assumes the form of a strap or band. The tendons of the brachial muscles, after passing within the annular ligament of the wrist, pass along the hand, and most of them along the fingers. They are confined on the hand by a membrane such as that just described, and on the fingers by ligaments, which retain them in their position in the same manner as that in which the annular ligament of the wrist acts. Thus we may conceive the tendons and muscles of the hand and fingers retained in their position by being enclosed in a membranous and ligamentous glove; and, in the same manner, those of the arm and humerus, by a membranous sleeve extending upwards from the superior edge of the annular ligament of the wrist.

132. **Muscles of the Leg.**—The muscular apparatus which moves the lower members has so close an analogy to that of the arms and hands, that it will admit of being rendered intelligible with much more brevity.

The muscles by which the infinitely various motions of the thigh are performed, are inserted at their lower extremities in different parts of the thigh bone, but chiefly at points a little below its articulation with the hip ; and at their upper extremities, at various points of the pelvic bones and some of the lower vertebræ. The dynamical effect of each of these will depend on the position of their point of insertion in the thigh bone, the position of their point of origin on the pelvic bones or vertebræ, and, in fine, on the course which the tendon takes in passing to the point of insertion. According as the point of insertion is on the outside, the inside, or anterior surface of the bone, the motion imparted will be outwards, inwards, or forwards ; and according as it is nearer to or more distant from the articulation, the motion will be more or less prompt and rapid.

Fig. 60.

133. When the great play allowed to the thigh by the ball and socket character of its articulation with the hip is considered, and when it is remembered that each particular muscle acting by itself upon a single tendon can only produce one motion, it may be expected that the muscles of the thigh must be very numerous. It is accordingly found that there are not fewer than sixteen connecting the thigh with the trunk, most of which are implanted in different parts of the pelvis, a few only having their origin in the vertebræ. Since, in general, the object to be attained is to give promptitude and rapidity rather than force to the motions of the member, the points of insertion in the thigh bone are, with a few exceptions, placed immediately

below the neck which connects the head of the bone with its shaft. They are there inserted principally in two protuberances, one inside and the other outside, called *trochanters*, which are shown at $43^{2}, ^{3}$. By these projections the advantage of a certain leverage is given to the muscles.

The more deeply seated muscles, connecting the pelvis with this part of the thigh bone, are shown in fig. 69, which presents a posterior view of the left hip-joint.

The muscles which surround the thigh bone between the hip and the knee are shown in figs. 70 and 71; the former presenting a posterior, and the latter an anterior view of the left thigh.

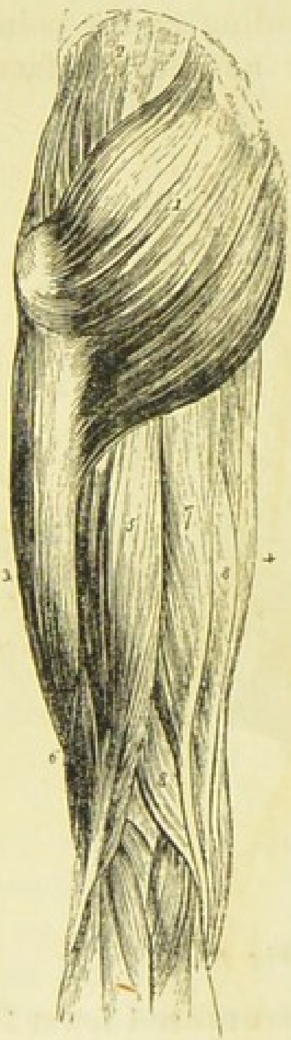


Fig. 70.

Fig. 71.

Of these muscles, 70^{1}, 70^{2}, 71^{1}, 71^{2}, 71^{3}, 71^{11}, 71^{12}, and 71^{13}, originate in the pelvis, have their insertions in the thigh bone, and are therefore motor muscles of the thigh. All

the others, passing below the knee, are inserted in one or other of the bones of the leg, of which accordingly they are either flexors or extensors, according as they are inserted in the posterior or anterior part.

134. The muscles which surround the bones of the leg, like those which invest the fore-arm, throw out long tendons, which, passing down the instep and to the heel, are inserted in the bones of the foot and toes in the same manner as those of the fore-arm are inserted in the bones of the hand and fingers. And in the same manner as the bellies of the muscles of the arm form the fleshy mass at its upper part, tapering into mere tendons at the wrist, the bellies of the muscles of the leg form the fleshy part of the calf, tapering as they descend into tendons which surround the instep and heel.

Fig. 72.

Fig. 73.

A front view of the superficial muscles of the left leg is given in fig. 72, and a back view in fig. 73.

The number of muscles which thus surround the leg is fourteen: seven in the anterior, and seven in the posterior part. Their tendons are connected, some with the bone of the heel; others, with the bones of the instep; others, with the phalanges of the great toe; and others throwing out several divergent tendons, which are inserted in the phalanges of all the lesser toes. This tendinous connection of the crural muscles with the bones of the foot and toes is shown in fig. 72. The calf of the leg is formed by the combination of the bellies of three muscles, two of which are connected by superior tendons with the thigh bone, and the other with the bones of the leg. The tendons of these muscles, coalescing towards the ankle, form a single tendon, 73, [6], which is inserted below in the extremity of the heel bone. This, which is by much the thickest and strongest tendon in the body, measuring about six inches in length, is that known as the tendon of *Achilles*, so called from the well known Homeric fable of its being the only vulnerable part of that warrior.

The great fleshy mass of the calf of the leg 73, [4], and the voluminous muscle 70, [1], upon the haunch or buttock, are among the anatomical peculiarities which distinguish man from the lower species.

The action of the muscles of the lower member is even more various and complicated than those of the arm. The reaction of the brachial muscles on the trunk, when their insertions in the arm are rendered fixed, are rare and exceptional, being manifested only in strained and unusual exertions of the body, such as that of climbing or the evolutions practised in gymnastic exercises. But the reaction of the muscles of the leg upon the trunk is habitual and constant, being always exerted when the body is erect and stationary. In that case, the insertions of the femoral and crural muscles becoming fixed, their tension is thrown upon the several points where their tendons and aponeuroses are inserted in the pelvis and lower vertebræ. Their effect in that case is to act as so many straps, by which the trunk is bound to the summits of the pillars formed by the legs, and held erect.

The flexion of the knee, when the body stands erect, is prevented by the force of the extensor muscles, which have their origin and insertion in the anterior parts of the bones of the thigh and leg; and in the same manner the leg is kept erect upon the foot by an equilibrium maintained between the tensions of the extensor and flexor muscles of the heel and instep.

Independently of these statical properties of the inverted action of the crural muscles, they have several important dynamical functions. Thus, when the trunk is inclined forwards, as in the act of bowing or stooping, the muscles inserted in the thighs, and originating in the lower vertebræ, play an obvious part—the insertions in that case becoming the

fixed points. If the muscles of both thighs conspire in this action, the trunk inclines forwards; if one only act, it inclines sideways.

The transverse direction of several of the muscles connecting the hip with the thigh, as may be seen in figs. 69, 70, together with the great mechanical advantage afforded to them by the length and obliquity of the neck of the thigh bone, fig. 43,[4], enables them to act in giving rotation outwards to the thigh, and with it to the whole member. In this, their analogy to the muscles connecting the scapula with the humerus is very conspicuous.

The muscles of the leg perform an important part in the actions of walking, running, and, still more, in the artificial exercises of dancing and gymnastics. In walking, the contraction of the muscles forming the calf draws the heel upwards, and places the sole of the foot in the position of an inclined plane. The trunk is thus projected forwards, and falls, in fact, but is arrested by the other leg, which is advanced during the elevation of the foot just mentioned. The same action is performed by the muscles forming the calf of the other leg, and the body is thus alternately projected forwards by the elevation of the one or the other heel.

Since the centre of gravity of the body is not placed vertically over each foot, but between them, the force imparted to it by the elevation of the heels will not be directly forwards, but a little sidewards, the left heel throwing it a little to the right, and the right heel to the left. This causes the alternate inclination of the body right and left, which takes place in walking. In persons having a tendency to corpulency, this lateral movement cannot be easily resisted, and they consequently have that particular gait called *waddle*. In persons having a wide pelvis, and legs short in proportion to the trunk, the pelvis, and with it the whole body, is turned alternately right and left in walking; so that when the right leg is put forward, the chest and face are perceptibly turned to the left, and when the left leg is put forward, they are turned to the right.

135. The muscles of the foot resemble, in all respects, those of the hand, the sole corresponding to the palm; and as all the muscles of the hand are collected on the palm, all those of the foot are collected on the sole. Their distribution on the sole is also similar exactly to the distribution of the muscles of the hand upon the palm. The muscles which move the great toe,

which is the analogue of the thumb, are placed on the inside, and those which move the little toe, the analogue of the little finger, on the outside; the centre of the sole being occupied chiefly by the tendons of the muscles of the leg, proceeding to the intermediate toes.

The superficial muscles of the left foot are shown in fig. 74, and the deeper ones in fig. 75. All these muscles act upon the

Fig. 74.

Fig. 75.

phalanges of the toes, in the same manner as the palmar muscles act upon those of the fingers.

In fine, a system of provisions for retaining the muscles and their tendons in their position, similar to that already described in the case of the arms and hands, is found in the leg and foot. An annular ligament, 72,[2], similar to that which surrounds the wrist, surrounds the instep, retaining in their place the tendons of the crural muscles which pass under it to the foot, and having the property of a fixed pulley in changing the direction of the force of these muscles transmitted along the tendons. A membranous coating, like that described in the case of the hand, invests the foot and toes, forming a sort

of sock by which the muscles and tendons are held in their places; and a similar web, forming a sort of stocking, invests the leg.

It may be observed, generally, that all these confining ligaments and membranes are supplied with a synovial apparatus by which their internal surfaces are lubricated, so as to give free play to the muscles and tendons within them.

CHAPTER IV.

THE STRUCTURE OF THE LOWER ANIMALS.

136. The bony frame-work and muscular apparatus, as they exist in man, are reproduced with more or less variation and modification in all the vertebrate animals. How large a part of animated nature is comprised in these may be judged when it is stated that, besides all the species of mammifers or animals which suckle their young, they include every variety of birds, reptiles, amphibia, and fishes.

In this region of nature the Creator has therefore worked upon one simple and uniform plan, modifying its proportions and details, and the number of some of its subordinate parts, to accommodate the structure to the external conditions in which each class and species is placed.

Although the comparison of the physical organisation of man with that of the lower animals exhibits in a striking manner all that he has in common with them, it renders manifest, at the same time, those provisions which set him conspicuously apart from, and exalt him immeasurably above them; and so profoundly impressed was the greatest of modern naturalists with this evidence of man's superiority, that he maintained that, without taking into consideration the reasoning faculty, man ought to be classified, not as a species of vertebrate animals, but as an order apart, presenting the anomalous example of being the sole genus of his order and the sole species of his genus.*

137. **Facial Angle.**—Physiologists have traced a general relation between the degree of intelligence manifested by different organised beings, and the volume and structure of the brain, not only when species is compared with species, but when individual is compared with individual: and some have pretended to push this induction even so far as to connect different parts of the brain with different faculties, passions,

* Cuvier.

and tendencies, founding their conclusions partly on observations of the brain in connection with the development of character, and partly on the analogies observable between the human brain, passions, and tendencies, and those of inferior animals. Hence has arisen that new branch of inquiry claiming a place in physiological science under the name of Phrenology.

The proportion which the part of the head occupied by the principal organs of sense,—those of seeing, hearing, smelling, and tasting,—bears to the part occupied by the brain and its appendages, is found to be a good general modulus of the power of the intellectual faculties ; and accordingly methods have been sought by physiologists, by which this proportion can be conveniently ascertained with some degree of approximation by external indications, independently of the results of dissection. The method which has been most generally received is that proposed by Camper, an eminent Dutch naturalist, which consists in measuring what he called the *facial angle*, formed by a line, *c d*,

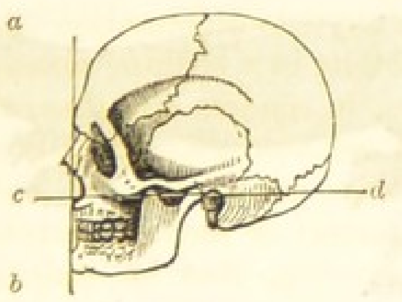


Fig. 76.

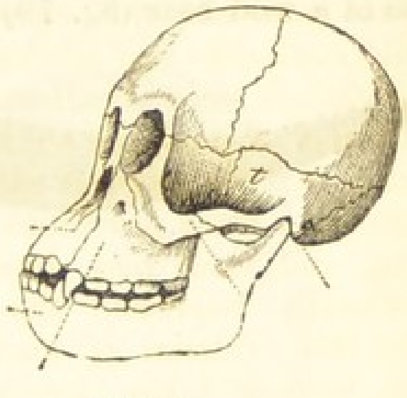


Fig. 77.

(fig. 76) drawn through the opening of the ear and the base of the nostrils, with another line, *a b*, drawn from the most salient point of the forehead, through the front of the upper jaw. This angle will be greater or less, according to the greater or less development of the brain, especially in its anterior part.

In comparing man with the inferior animals, it is found accordingly, that his facial angle exceeds those of the latter in a large proportion ; and in comparing different species of animals one with another, the variation of this angle is in remarkable accordance with their several manifestations of intelligence.

The following are the facial angles of certain species, according to different physiological authorities :—

Man (European) (fig. 76).	85° to 90°
Ourang-Outang (fig. 77)	56° to 60°
Apes (fig. 78)	30° to 65°
Dog	35°
Ram	30°
Horse	23°

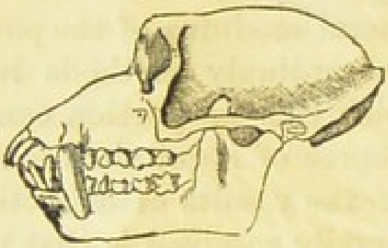


Fig. 78.

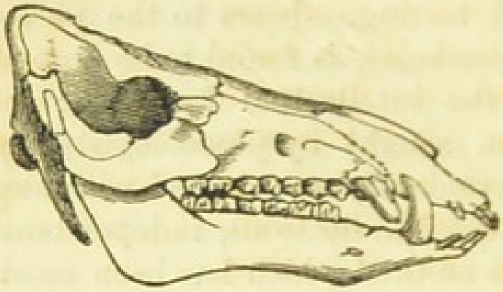


Fig. 79.

According to Professor Milne Edwards, the forehead in the case of a wild boar (fig. 79) is so formed, that it is impossible to

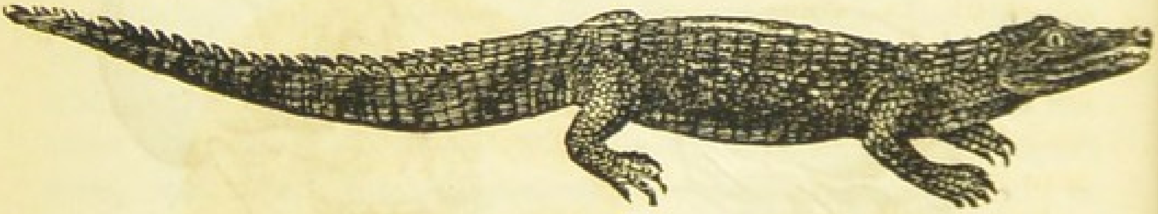


Fig. 80.
CROCODILE.

draw a straight line from the upper jaw to the most prominent part of the skull, the latter falling considerably behind the bony projection of the nose.

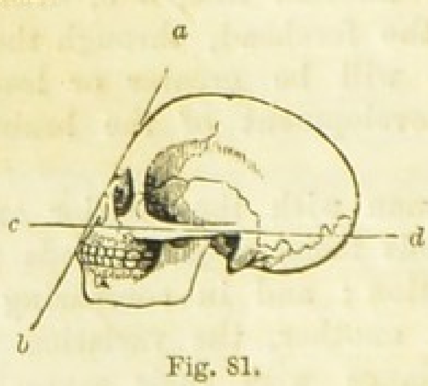


Fig. 81.

With birds and fishes the facial angle is less than with mam-

mifers, and with reptiles (fig. 80) is often so small as to be scarcely appreciable.

In comparing individuals of the human race existing in different climates and under different physical influences, the facial angle is subject to much variation. Thus, while with the European (fig. 76) it is sometimes so great as 90°, with the negro (fig. 81) it seldom exceeds 70°.

The character which the facial angle imparts to the physiognomy is very apparent in comparing, one with another, the several varieties of the human race.

Although the more complete investigation of the connection of cerebral development with the extent of the intellectual faculties was reserved for modern investigators, it does not appear to have escaped the notice of

Fig. 82. (R. An.) *
EUROPEAN.†

Fig. 83. (R. An.)
MONGOL. ‡

* The figures throughout this volume bearing this reference have been copied by permission of the authors and publisher, from the magnificent atlas of the Règne Animal, by MM. Audouin, Blanchard, Deshayes, d'Orbigny, Doyère, Dugès, Duvernoy, Laurillard, M. Edwards, Roulin, and Valenciennes, and published by M. Victor Masson, Paris.

† From a Portrait of Suwarrow.

‡ Portrait of a native of Kamchatka.

the ancients, who evidently saw in the facial angle an index of intelligence. Not only do we find in their writings an erect frontal line noticed as a mark of a generous nature and an essential character of beauty, but the ancient sculptors conferred upon the figures of their heroes and their gods a facial angle much larger than is ever seen in man; and in some of the more remarkable statues which have come down to us,—the Olympian Jupiter for example,—the frontal line *b a*, fig. 76, actually inclines forward so as to render the facial angle obtuse.

Fig. 84. (R. An.)
ALFOUROUX.*

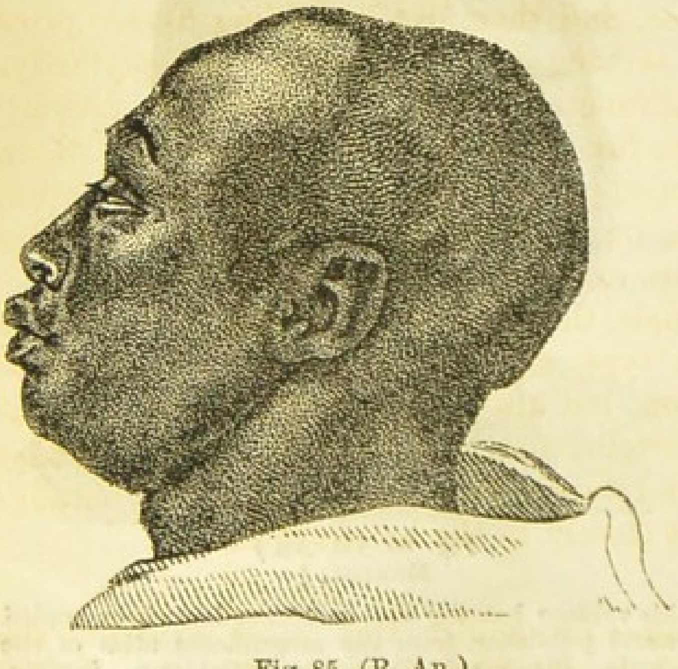


Fig. 85. (R. An.)
NEGRO.

Even the most vulgar observation ascribes stupidity to a projecting mouth and nose and retiring forehead, to which the name *muzzle* is given, whether found in men or in animals. And when in exceptional cases an apparent enlargement of the facial angle is pro-

* A Native of New Holland, from a Portrait of Ourou-Maré, a warrior of the Tribe of Gwea-Gul.

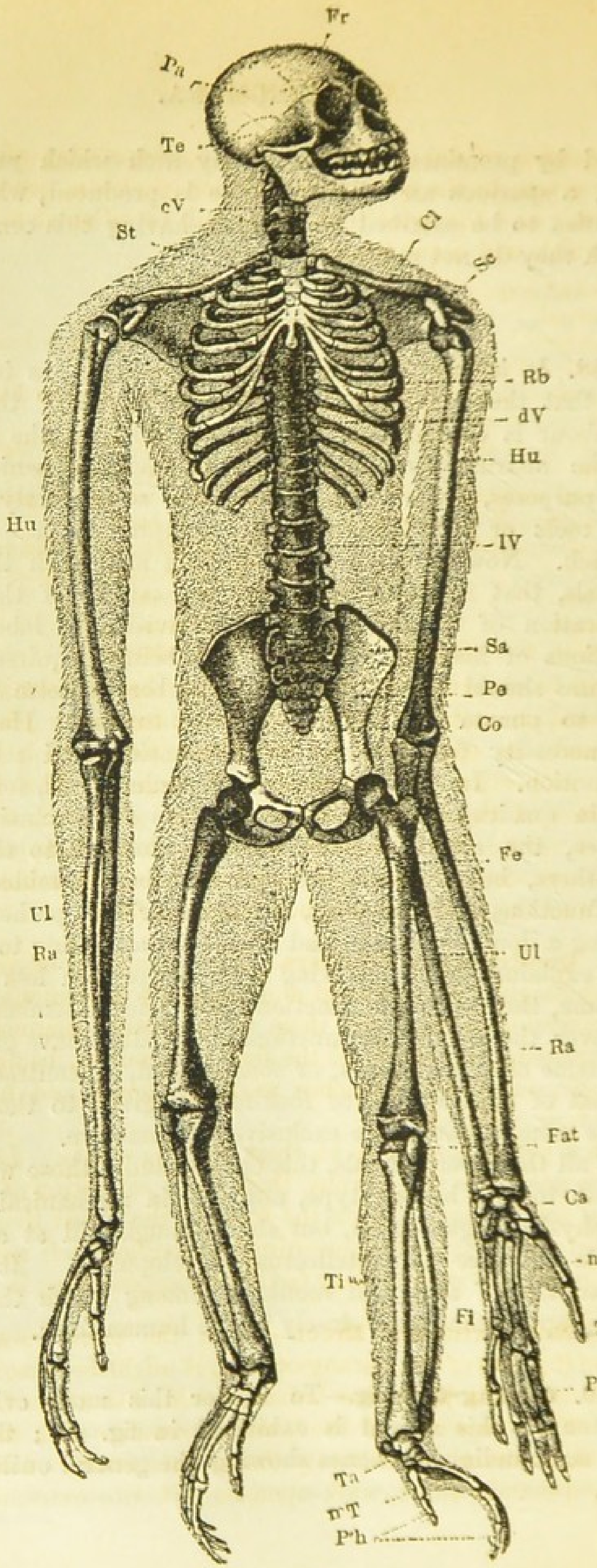
duced by prominence of the bony arch which protects the eyes, a spurious air of intelligence is produced, which causes qualities to be ascribed to animals having this conformation, which they do not really possess.

QUADRUMANA.

138. It is found in the works of nature, as in those of art, that the more extensively the principle of the division of labour is carried out, the greater will be the perfection of the instruments. A tool or a machine, which attains two purposes, attains neither of them so perfectly as would two tools or machines especially adapted to the execution of each. Now we find, on comparing man with the inferior animals, that he supplies a solitary example of the rigorous application of the principle of the division of labour in the functions of his members. Its well-being requires that the creature should be supplied with members to seize and members to pursue the objects of its nutrition. Hence arises the necessity for members of prehension and members of locomotion. In some of the inferior animals, as, for example, certain quadrupeds, the four members are exclusively locomotive, the act of prehension being confined to the mouth. In others, however, all the four members, besides fulfilling the functions of locomotion, are more or less prehensile, thus serving a double purpose, and therefore, according to the principle explained above, serving it by comparison less perfectly. In some, the prehensile functions of the four members prevailing over the locomotive functions, naturalists have given them the name of *quadrumana*, or four-handed, in contradistinction to that of quadrupeds, or four-footed, given to those species whose members are more exclusively locomotive.

Of all the lower animals, this class includes those which come nearest to the human type, not only in mechanical structure and physical organisation, but also—though still at an immeasurable distance—in intellectual development. It includes all varieties of apes and monkeys, among which the ourang-outang approaches most closely to the human form.

139. **Ourang-Outang.**—To render this more evident, the skeleton of this animal is exhibited in fig. 86; the shaded parts surrounding the bones showing the general outline of the body.



Fr
Pa
Te
cV
St
Cl
Sc
Rb
dV
Hu
Hu
lV
Sa
Pe
Co
Fe
Ul
Ra
Ul
Ra
Pat
Ca
mC
Ti
Fi
Th
Ph
Ta
mT
Ph

Fig. 86. (R. An.)

The names of the various bones, corresponding with those already given, in the case of the human skeleton, are indicated as follows ; and the same indications will be adhered to in other cases, which will occur hereafter.

Fr.	Frontal bone.
Pa.	Parietal.
Te.	Temporal.
cV.	Cervical Vertebræ.
St.	Sternum, or breast-bone.
Cl.	Clavicle, or collar-bone.
Sc.	Scapula, or shoulder-blade.
Rb.	Ribs.
dV.	Dorsal vertebræ.
Hu.	Humerus, or upper arm.
lV.	Lumbar vertebræ.
Sa.	Sacrum.
Pe.	Pelvis.
Co.	Coccyx.
Fe.	Femur, or thigh-bone.
Ti.	Tibia.
Fi.	Fibula.
Ul.	Ulna, or inner bone of fore-arm.
Ra.	Radius, or outer bone of fore-arm.
Pat.	Patella, or knee-cap.
Ca.	Carpus, or wrist.
mC.	Metacarpus, or palmar bones of hand.
Ph.	Phalanges, or fingers.
P'h.	Phalanges, or toes.
Th.	Thumb.
Ta.	Tarsus.
mT.	Metatarsus.

It will be observed that the feet have the conformation and mechanical character of hands, the great toe being placed, like the thumb, in opposition to the other toes, which have the length, proportion, and structure of fingers. The beautiful application of the principle of the division of labour, observable in the structure of the human members, here disappears, with its consequences, the anterior members being as much feet as hands, and the posterior as much hands as feet.

140. **Quadrumana Climbers.**—This structure of the members, which gives an awkward and ungainly movement to them in ordinary locomotion, fits them in a peculiar manner for the act of climbing, in which all the four extremities, being equally prehensile, grasp the branches as they mount and leap from tree to tree. Fig. 87.

Such a power is suitable to their organic wants. Like man, they are naturally frugivorous, their teeth consisting of incisors, canines, and molars. Upon the trees of the forest their food is produced ; and Nature has, accordingly, modified their members so as to give them every necessary facility for approaching it. Fig. 89.

141. **Not Naturally Erect.**—From the mere view of the skeleton (fig. 86) of the ourang-outang, it might be imagined that the natural attitude of that animal would, like that of man, be erect. The comparison of the lower extremities with the human feet will, however, immediately dispel this error. Although it can, by a certain effort, walk upon its posterior extremities, the

gait is awkward ; and the action cannot be long continued without the aid of a staff, which the animal is generally trained to use

Fig. 87.
THE OURANG-OUTANG.

for the purposes of exhibition. Left to himself, he will always relieve himself by using his anterior extremities for partial support (fig. 88) ; and, to enable him to accomplish this without too great an inclination of the axis of the body, the extraordinary relative length, shown in the figure, is given to these members.

142. **Prehensile Tail.**—The double purpose of prehension and locomotion assigned to the members of the quadrumana, and their habitual exercise of climbing in pursuit of their food, and for protection from their enemies, render the occasional aid of another organ of prehension necessary ; such an organ is accordingly supplied them in the tail. In fig. 89 is represented the white-throated monkey thus exercising this prehensile action. The same action is common with the species called the *Coaita*, or spider-monkey, so named from the extraordinary length of its extremities, and from its motions. "The tail," says Sir Charles Bell, "answers all the purposes of a hand, and the animal

throws itself about from branch to branch, sometimes swinging

Fig. 88. (R. An.)

by the foot, sometimes by the fore extremity, but oftener and with greater reach by the tail. The prehensile part of the tail is covered with skin only, forming an organ of touch as discriminating as the proper extremities. The *Caraya*, or black howling monkey of Cumana, when shot, is found suspended by its tail round a branch. Naturalists have been so struck with this property of the tail of the *Ateles*, that they have compared it to the proboscis of the elephant, and have assured us that these monkeys fish with their tail.

"The most interesting use of the tail is seen in the opossum. The young of that animal mount upon her back, and entwine

Fig. 89. (R. An.)
THE WHITE-THROATED MONKEY.

their tails round their mother's tail, by which they sit secure while she escapes from her enemies." *

It will be observed that the young one, represented in fig. 90, also uses its tail as an organ of prehension, holding itself upon the body of its mother by twining the tail round her.

The varieties of these animals do not all exhibit the same close resemblance to the human form. Many have the appearance of quadrupeds; some, such as the mandrill (fig. 91), resembling in their general form the dog.

QUADRUPEDS.

143. While Nature has given to the tribes above referred to four members, more prehensile than locomotive, she has bestowed on a far more numerous class of animals four members which are either exclusively, or chiefly, locomotive and susten-

* Bell on the Hand, p. 19.

tatory, from which character they have received the general denomination of *quadrupeds*.

Fig. 90. (R. An.)
THE KAMI.

Fig. 91. (R. An.)
THE MANDRILL.

However striking may be the difference between these and man, the skeleton is composed of the same parts; the powers of locomotion peculiar to each species being produced, for the most part, by the mere variation of the relative lengths of the bones and some slight modifications of the joints.

The general structure of the skeleton of quadrupeds may be illustrated by that of the camel, shown in fig. 92, the outline of the body surrounding the bones being, as before, indicated by the black shading.

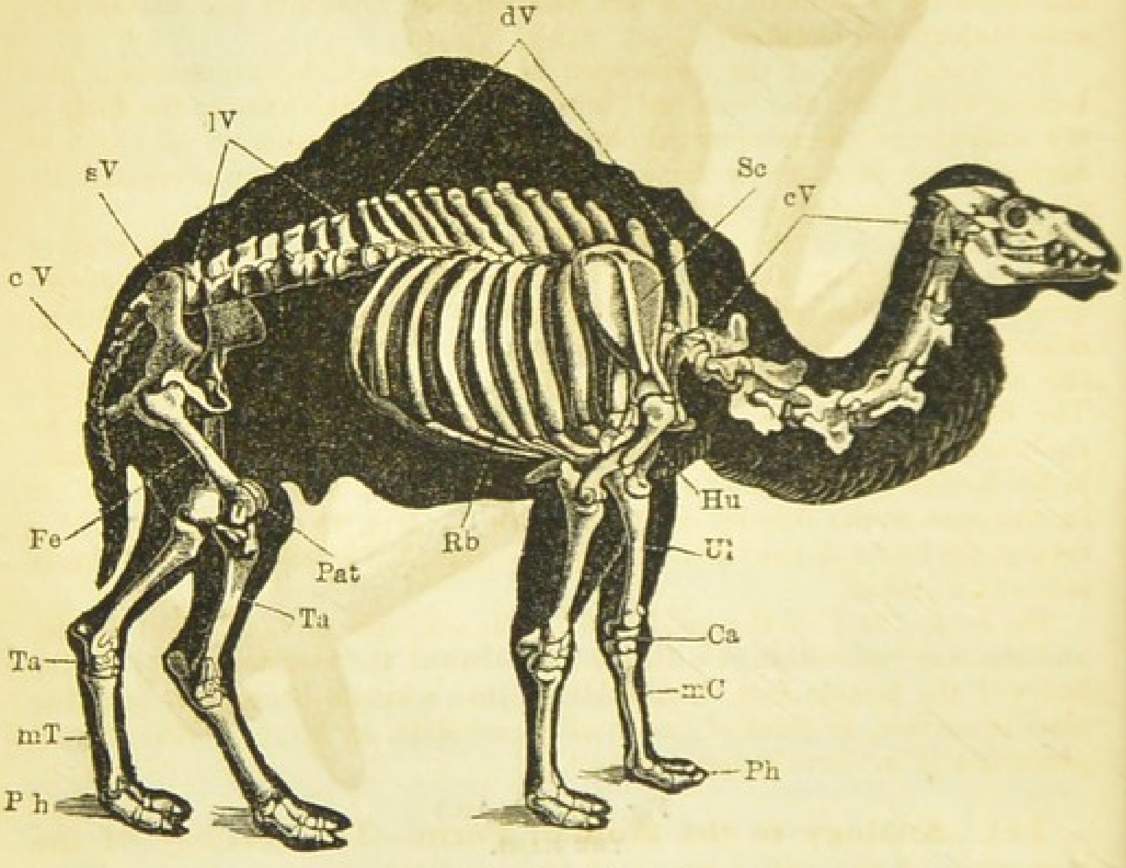


Fig. 92. (R. An.)

The various bones corresponding with those of the human skeleton, are marked by the same letters as have been already adopted in the case of the ourang-outang (fig. 86). They need not, therefore, be again explained. In the present case, however, sV and c′V have been added, indicating the sacral and caudal vertebræ.

How important a change has been produced by a mere variation of length of some principal, and decrease of number of some subordinate bones will be perceived by comparing the skeleton of the human hand and arm with the corresponding part of the fore-leg, as here shown. The humerus, or bone of the upper arm, which extends from the shoulder to the elbow, and in man is the longest bone of the arm, is here (Hu.) reduced in length, and buried in the flesh of the breast. The joint which corresponds to the human elbow is that which more immediately connects the summit of the

leg with the body. The bone (Ul.) of the leg extending from this joint to the knee of the animal is that which corresponds to the principal bone (the ulna), of the fore-arm, and which extends from the elbow to the wrist.

The radius is suppressed, or may be considered as cemented to the ulna, so that both form a single bone. The reason of this modification will be apparent if the peculiar function of the radius be taken into consideration. That bone, it will be remembered, constitutes the mechanism by which the hand is rendered capable of turning round the axis of the arm, so that the palm may be presented in any desired direction, without any change of position of the arm. This being a function peculiar to the prehensile character of the hand, and incompatible with the stability requisite for an instrument of sustentation and locomotion, it is consistently suppressed in the structure of animals, of which the anterior members are exclusively sustentatory and locomotive.

The knee (Ca.) of the quadruped is the joint which corresponds to the human wrist; and the bone (mC.), extending from the knee to the foot, is the analogue of the metacarpal bones of the hand, the number of which is here reduced to a single bone. In fine, the fingers are represented by the toes, the number of which is here reduced to two (Ph.).

The hind legs of the quadruped correspond to the lower members of the human skeleton, and the comparison of them will produce like consequences. The thigh-bone (Fe.), the longest of those of the human skeleton, is here relatively short, and buried in the haunch. The joint which connects the hind leg with the body is that which corresponds to the human knee. The bone extending from this to the hock is that which corresponds to the bones of the leg, extending from the knee to the ankle. These bones, which in the human skeleton are two, the tibia and fibula, are here reduced, as in the case of the fore-leg compared with the arm, to a single bone which retains the name of the tibia, and may be regarded as the tibia and fibula soldered together.

The hock (Ta.) of the quadruped is the analogue of the human ankle, and the bone connecting it with the foot, that of the metatarsal, or instep bones of the human foot, here soldered into a single bone. In fine, the plantar surface, or point of sustentation, consists, as before, of the toes or phalanges (P′h.) here reduced to two.

144. **Analogy to the Human Form.**—The analogy of the structure of the other parts of the skeleton to that of the bony frame-work of the human body will be obvious from the indications on the figure without much detailed explanation. The head, being heavy and attached to the extremity of a long and flexible series of cervical vertebræ, and therefore requiring adequate support, a system of powerful muscles is provided by which it, as well as the neck to which it is attached, is connected with a series of long spinous processes issuing obliquely backwards from the dorsal vertebræ.

On the other hand, the vertebral column not requiring the same power of inclination towards the abdominal region as it does in man, there are few or no flexor muscles corresponding with those which act on the human skeleton.

The structure of the leg is subject to some variation in different quadrupeds, though retaining the analogies to the human members which have been indicated above.

145. **Legs and Feet.**—When an animal is supported on four feet, the extent of its base of sustentation, and therefore its stability, cannot be augmented in any sensible degree by extending the magnitude of its plantar surfaces. The case is quite otherwise with bipeds, whose base of sustentation, other things being the same, will be in the direct ratio of the length of their feet. To have augmented the magnitude of the plantar surface of the feet of quadrupeds would have increased their weight, and diminished their speed and activity, without conferring upon them any countervailing advantage. Nature, therefore, while she gave bipeds stability by making them walk on the soles of their feet, gave quadrupeds lightness and swiftness by making them walk on their toes.

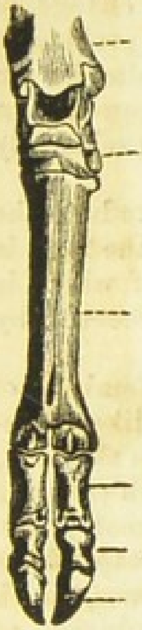


Fig. 93.

It is found, that in proportion as greater powers of speed are conferred on quadrupeds, the plantar surfaces of their feet and the number of their toes are diminished.

In fig. 93, is represented the lower part of the hind leg of the deer, the same letters of indication being retained as in the former figures. The lower end of the tibia, or leg-bone, is jointed with the metatarsal bone (mT.) at the hock (Ta.) which corresponds with the human ankle. The metatarsal bone (mT.) is articulated to the foot, which is flexible, and rendered highly elastic by its flexor and extensor muscles, and consists of a succession of three joints (Ph., P'h., P''h.), which correspond to those of the human toes, but are relatively larger, and possess a greater play of flexibility and extensibility. The toes are reduced in number to two, and the nails are developed into the cloven hoof characteristic of the animal.

In fig. 94, is represented, in like manner, the hind leg of the horse, with like letters of indication. Here two rows of tarsal bones (Ta.) and (Ta'.) appear, as also a projection, t, representing the thumb in a rudimentary state. The toes are reduced to one, the nail of which is developed into the solid hoof.

146. **Action of the Muscles.**—The motion of the legs and the action of the muscles from which such motion immediately proceeds, are such as to impart to the centre of gravity of

the body a series of impulses directed forwards and very slightly upwards; the descent of the body between impulse and impulse being so regulated, that no injurious shock is produced when it is caught successively by the members put forward to receive it.

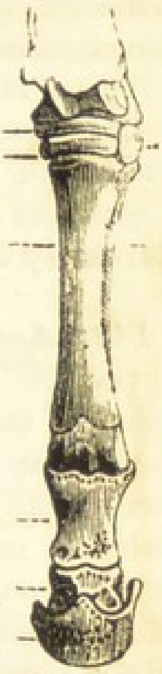


Fig. 94.

In giving the impulse to the body the member acts like a spring which, after being bent, restores itself to its primitive form by virtue of its elasticity. The limb is bent at each of the joints by the action of the flexor muscles, so that each part is inclined to the parts with which it is articulated at an angle more or less obtuse. The member, then, having its lower extremity firmly supported on the ground, straightens itself by the action of the extensor muscles, and in so doing projects the centre of gravity of the body forwards and slightly upwards. While this takes place, the other member has been thrown forwards, and its lower extremity is planted upon the ground to give support to the weight of the body thus thrown forwards.

In the case of man the connection of the thighs with the pelvis has an important relation to these movements. Had the hip-joint been made on a plan similar to the knee-joint, the action necessary to the progressive motion of the body would have been, if not impossible, at least awkward, ungainly, and inefficient. The peculiar articulation of the head of the thigh-bone with the external angle of the pelvic bone gives free play to the pelvis so that it can turn horizontally on the thigh-bone as an axis. When the legs are alternately advanced, this power is brought into play, the horizontal displacement of the pelvis in relation to the legs being more or less in different individuals.

147. **Effect of Standing.**—As has been already observed in reference to the human body, the attitude of standing at rest is far from being one in which the physical forces are inactive. The members, being all more or less flexible at the joints, would bend under the incumbent weight of the body if their rigidity were not maintained by the action of the extensor muscles. The continuance of such action absorbs an amount of muscular

energy proportioned to the incumbent weight of the body, and to the length of the interval during which the action is continued without intermission.

Hence it arises that with animals, as with man, standing erect at rest is often more fatiguing than locomotion; inasmuch as in the former case the same set of muscles is kept in constant action, while in the latter different sets are brought alternately into play.

148. **Action of the Hind-legs.**—The power of quadrupeds to project their bodies forward depends much more on the action of the posterior than on that of the anterior members. The latter are chiefly useful for the support of the anterior part of the trunk, while its mass is projected forward by the posterior members. Strictly speaking, therefore, the anterior members ought perhaps to be denominated organs of support, rather than organs of locomotion. The fore-legs are alternately raised from the ground, it is true, and the feet are thrown forward ; but this is for the purpose of enabling the leg to catch the body as it falls, after being projected forwards and slightly upwards by the posterior members.

149. **Bounding Animals: the Kangaroo.**—In animals whose habits require a great bounding power, the members are constructed in accordance with the principles here explained. The posterior members have great proportional length, the anterior members being comparatively diminutive. By the pliability of its spine, and the flexibility of its posterior members, the animal can place itself preparatory to a bound so that, the lower bones of the leg being horizontal, the two superior bones shall be inclined to them at something less than a right angle, as shown in the case of the kangaroo (fig. 95) ; the profile and skeleton of which are represented in fig. 96. It may easily be perceived how powerful must be the bound which such an animal, or one such as the jerboa, or jumping-mouse (fig. 97), can make. A like structure is observable, though in a less exaggerated proportion, in the hare and rabbit, which run by bounds ; and in the cat and tiger, which pounce upon their prey.

150. These proportions are reversed in quadrupeds of slow locomotive powers, of which the giraffe is one of the most remarkable examples. In this animal a great proportionate length is given to the fore-legs, so that, notwithstanding

Fig. 95. (R. An.)
KANGAROO.

Fig. 96. (R. An.)

Fig. 97. (R. An.)
THE JERBOA, OR JUMPING-MOUSE.

the length of its neck, it would be incapable of taking its food from the surface upon which it stands. Nature has, however, beneficently adapted its wants to its structure; and while she has elevated its head to a height of twenty feet above the ground, she has supplied it with nourishment at a corresponding elevation in the foliage of trees. The only known species of this animal inhabits Africa.

151. **Fossil Quadrupeds: Cervus Megaceros.**—The ani-

Fig. 98.
CERVUS MEGACEROS.

mal remains which have been discovered in the researches of

geologists show that Nature, during those remote periods of time which preceded the present creation, worked upon the same general plan in the construction of animals as that which characterises the races which now inhabit the globe.

Innumerable fossil remains of quadrupeds offer incontestable evidence of this. In fig. 98 is presented one of the most remarkable examples of fossil quadrupeds. This is a species of stag called by geologists the *Cervus megaceros*, found in the bogs of Ireland and in many other parts of Europe. The extreme spread of the horns of this animal measured ten feet.

The analogy of the various parts of the skeleton to those already shown in fig. 92, is so obvious that it is not necessary here to particularise them.

152. **Megatherium Cuvieri.**—This animal, which is one of the most extraordinary results of geological research, belongs to a genus which has never existed upon the earth during the period of its habitation by the human race. The skeleton (fig. 99) was more than thirteen feet in length, and nearly ten in height. The haunches measured more than five

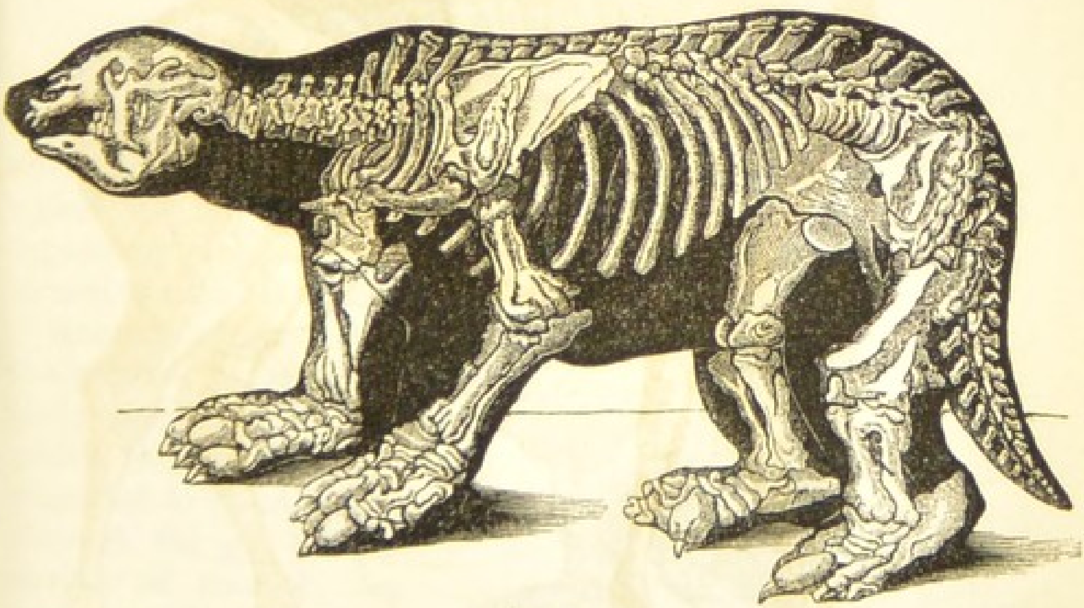


Fig. 99.
Megatherium Cuvieri.

feet in breadth, dimensions which greatly exceed those of the corresponding bones of the largest existing elephants. The thigh bone was enormous, its diameter being more than half its

length, a proportion without example in any living species. The head, like those of the varieties of the sloth, was small compared with the body, and the tail consisted of numerous vertebræ. The forms of its teeth proved that the animal was neither herbivorous nor carnivorous, but fed upon succulent roots, which it dug from the earth. Its prodigious tail served in certain attitudes as an organ of sustentation, and probably also as an instrument of defence. The articulation of its fore-legs and the structure of the phalanges indicate the use of that member in digging for food. The body was supported by the hind legs and one foreleg, and partly perhaps by the tail, while the other foreleg was employed in digging. The great magnitude of the pelvis also favoured this action. The remains of this animal are found in the tertiary strata of the Pampas of Buenos Ayres, and in the caverns of Brazil.

153. **Mylodon robustus**—Owen (fig. 100). Like the me-

Fig. 100.
Mylodon Robustus.

gatherium, this genus, also extinct, resembles the sloth, and

is found in the same strata. Its dimensions are not nearly so great, but it differs in structure from the latter only in the character of its teeth, which prove it to have been herbivorous, feeding on leaves and tender shoots.

Not only the particular species of mammifers of which specimens have been given above, are limited to the tertiary rocks, but no remains whatever of any mammifers are found below them.* In these tertiary rocks, 115 different genera have been found, and these increase gradually in ascending. Thus, while the lowest stratum contains only 6, the next superior to it contains twenty-one, the next fifty-seven, and the upper stratum (the Parisian of the French geologists) seventy-two.

When it is considered that these strata represent a series of successive periods in the chronology of the globe anterior to the actual epoch, and that the number of living genera of mammifers is 210, it will be apparent that Nature, in the production of this her most perfect work of animal organisation, has gone on progressively augmenting her operations; and since man, the most perfect of all, has only appeared in the actual epoch (no human fossil being discovered in the tertiaries, still less in any of the older strata), it follows that while she augmented the number of her works she also exalted their excellence.

Of the total number of fossil genera, sixty-four are extinct, and fifty-one are comprised among existing mammifers.

BIRDS.

154. **Animals which Fly.**—Although the conditions under which the inhabitants of the air and water live, and the movements they have to execute, differ so extremely from those to which we have hitherto referred, it is surprising by what apparently simple means nature has rendered the same general structure suitable to functions so different.

Animals which walk, or otherwise move upon the surface of the ground, have a firm and unyielding support against which their organs of locomotion react, so that the whole muscular force which they exert is immediately absorbed by the momentum imparted to their bodies. In the case of animals which move through the air, however, so far from possessing such a fixed surface of reaction, the organs of locomotion have nothing whereon to support themselves or to act, except the lightest and most attenuated of natural fluids. The mechanical conditions of propulsion are therefore in this case wholly different. The organs of locomotion acting upon the air, impart to a certain

* Remains have been found in two cases only in the middle strata of the Jurassic group, which have been conjectured to be mammiferous.

volume of it a moving force in a direction contrary to that in which the animal intends to move. By the general principle of the equality of action and reaction, the body of the animal receives an equal moving force, and if no impediment were presented, it would be moved forward with exactly as much force as that with which it had driven the air backward; but its velocity would be just so much less than that with which the air is propelled backwards as the weight of the air thus propelled is less than the weight of the body of the animal.

155. **Their Locomotive Apparatus.**—But it is obvious that, in moving forward, the body of the animal passing through the air must displace so much of that fluid as is equal to its own volume, and consequently must impart to it a certain moving force; and whatever be the amount of that moving force, it will be necessarily deducted from the force of propulsion which had been given to the body of the animal, the progressive motion of which will therefore be, not the whole moving force with which it drove the air backwards, but the difference between that force and the moving force which it gives to the air which lies in its way in passing through it.

To render the locomotive power of the animal, therefore, as efficient as possible, two conditions should be fulfilled by its locomotive mechanism: first, such arrangement should be provided as will enable it to propel backwards as great a volume of air as possible; and secondly, its form and structure should be such as to displace as small a quantity of air as possible in moving forwards. We shall see presently that in the structure of birds nature has fulfilled these mechanical conditions with the same admirable perfection which is observable in all her other works. The members which correspond to the arms and hands in men are the organs of flight of the inhabitants of

Fig. 101. (R. An.)

the air, and they are constructed accordingly, with modifications which render them suitable for this purpose.

156. **The Bat.**—There are some animals of the class of

Fig. 102. (R. An.)

mammifers which, exercising certain powers of flight, may in this respect be considered as holding an intermediate place between these and birds. Of this class, the bat (fig. 101) is an example, which is represented by its skeleton in fig. 102.

To produce the organs of flight, in this case, the only change of structure consists in increasing the proportionate length of the fore-arm (Ul.), and in a much greater degree, that of the fingers (Ph.); the thumb (Th.) being rudimentary and inactive. The fingers and arm are connected with each other, and with the legs, by an extensive web; and by its muscular power, the animal being able to separate the fingers, this web becomes stretched like a sail, and thus re-acts upon the air.

157. **Birds.**—Although the skeleton of birds differs more than that of the bat from mammifers in general, it nevertheless retains all the essential characters of the solid framework of vertebrated animals, the points in which it differs having chiefly reference to the powers of aerial locomotion. And here again we have reason to admire the very simple modifications by which the skeleton has been thus adapted.

In figure 103 is represented the profile and skeleton of a vulture, and in fig. 104, that of a gull, the bones which correspond to those of mammifers being indicated on the figures respectively.

158. It will be evident by inspecting the indications on these figures, that the framework of the bird in all essential particulars is constructed upon the same general principles as

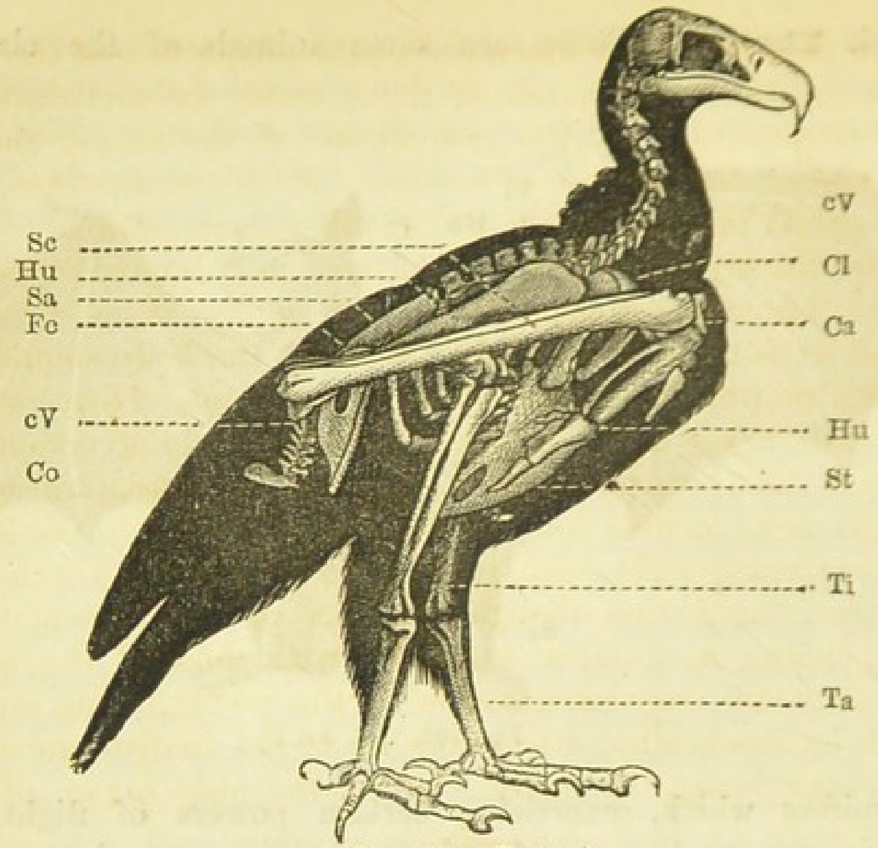


Fig. 103. (R. An.)

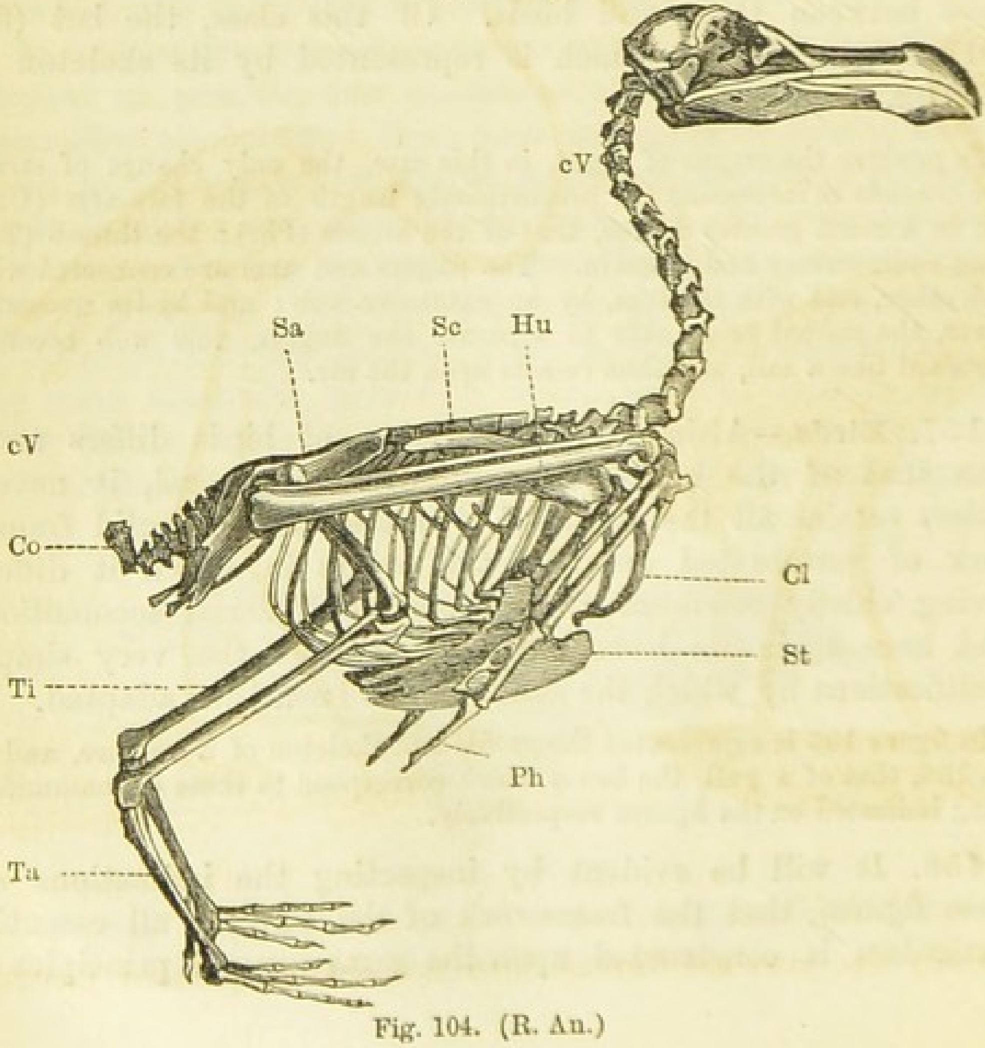


Fig. 104. (R. An.)

that of man and other mammifers ; the adaptation of the hands and arms to the purposes of flight being accomplished by a mere modification in the proportion of the bones, and the reduction of the number of fingers. There are, however, some other points in the skeleton which will require notice.

Since the organs of locomotion have not only to propel the animal, but also to support it when it has risen from the ground, it is essential that the weight of the body should bear the smallest practicable proportion to its volume. Hence we find that birds never attain to the great magnitude of mammifers, and that their bones and other parts of their system are so constructed as to include considerable cavities, so as to render the body extremely light with relation to its bulk. The head is in general small ; and though composed of independent bones, corresponding in number and form with those of the human skull, they are only recognisable in the young, being so connected by ossification afterwards as to be undistinguishable. The mouth being, in many species, the only organ of pre-

Fig. 105. (R. An.)
THE CRANE.

Fig. 106. (R. An.)
THE FLAMINGO.

hension, the jaws are formed into two oblong, pointed pieces,

coated with a horny covering, which constitute the bill, the form and magnitude of which is subject to much variation, being in every case adapted to the nature of the food on which the animal subsists.

159. **The Neck and Head.**—The articulation of the head with the vertebral column gives it much greater freedom of motion than is generally found in mammifers. The length of the neck, which is extremely flexible, is proportionate to the height of the body—a condition necessary to enable the animal with sufficient facility to pick up its food. In the case of certain aquatic birds which seek their food at a considerable depth in the water upon which they float, a still greater length is given to the neck, as may be seen in the instance of geese and swans.

In all cases, the cervical vertebræ are so articulated as to give the utmost possible freedom to the movement of the head; and this is especially the case with birds like the crane (fig. 105), and the flamingo (fig. 106), which, to seize their prey, must dart their bill with great rapidity to a considerable distance. In all such, numerous muscles are provided, attached to suitable processes in the cervical vertebræ, by the action of which these motions are imparted.

160. **Dorsal Vertebræ.**—While the cervical vertebræ of birds are thus constructed with such perfect mobility, all the articulations of the dorsal vertebræ are, on the contrary, absolutely ossified, so as to render that part of the spinal column a single, strong, solid bone.

161. **Birds which do not Fly.**—The mechanical reason for this modification is as apparent as that which explains the extraordinary freedom of the neck. The scapula upon which the wing plays is attached to the ribs, and by them to the dorsal vertebræ; and it is evident that the force by which the wing must react upon the ribs, and through them upon the dorsal part of the column, would be altogether incompatible with the flexibility given to that part of the column in mammifers. The dorsal vertebræ of the bird, therefore, are soldered together in order to give a firm point of reaction to the wings. That this is the true explanation of the rigidity of the dorsal part of the spinal column is rendered manifest by the fact that in the case of birds, such as the ostrich (fig. 107), and the cassowary, (fig. 108), which never rise from the ground, and whose locomotion is limited to walking and running, the dorsal vertebræ have flexible articulations, like those of mammifers.

162. **Locomotive Functions of the Tail.**—The vertebræ of the coccyx (figs. 103 and 104) are articulated so as to give them a certain play; and the last of these has an increased magnitude and a projecting position, being the part to which the principal feathers of the tail are attached. The flexibility of the coccygian vertebræ has an important relation to the locomotive powers of the bird; the feathers of the tail, whose position they govern, acting as a sort of rudder in guiding the flight of the bird through the air.

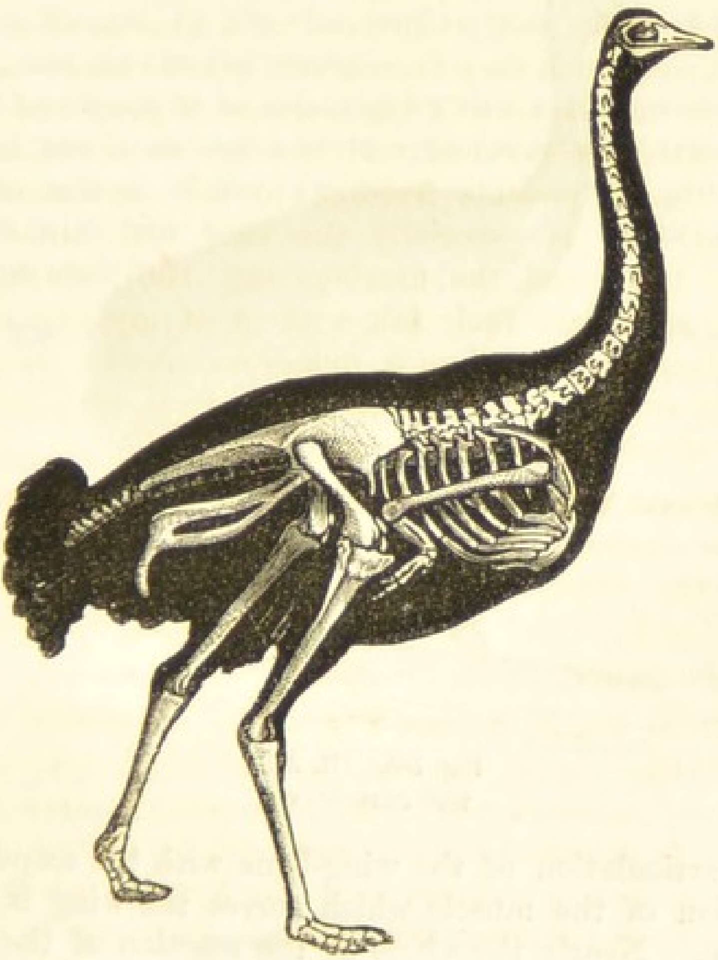


Fig. 107. (R. An.)
SKELETON OF THE OSTRICH.

163. **The Thorax.**—It will be recollected that, in man and other mammifers, the ribs are connected in front with the breast-bone by certain cartilaginous straps. Now, it is evident that, in the case of birds, such a mode of connection would be quite incompatible with that solidity and firmness which is necessary to resist the action of the wings transmitted to the ribs through the scapula. We find, accordingly, that those parts of

the ribs connected with the sternum which in mammifers are cartilage, in birds are bone.

But there is another provision, still more admirable, to supply a resisting power to the ribs proportionate to the vast force exerted in flight by the wings. To appreciate this force and the necessity for providing a suitable resistance against it, it must be considered that, when the expanded wing acts upon the air, the centre of pressure is at a considerable distance

Fig. 108. (R. An.)
THE CASSOWARY.

from the articulation of the wing-bone with the scapula, while the insertion of the muscle which moves the wing is near the articulation. Nearly the whole of the reaction of the air upon the wing is thrown upon the scapula, by the scapula on the ribs, and by the ribs is distributed between the spinal column and the sternum. The ribs being semicircular, or semi-elliptical hoops, may be regarded as forming an arch, of which the spine and the sternum are the abutments, upon which, therefore, the entire reaction of the wings must ultimately fall.

164. **The Breast-bone.**—The form given to the breast-bone of birds, as compared with the sternum of mammifers, supplies another admirable example of the adaptation of means to an

end. Every one is familiar with the form of the breast-bone of a fowl. It is a sort of inverted arch, not unlike the lower part of the hull of a ship ; and, like the hull, it is strengthened by a keel, which extends along the middle of its entire length. To the edges of this strong, bony, inverted arch, the ends of the ribs are firmly attached, not by articulations, but by solid ossified connections (fig. 104). In the same figure, it may be seen that, from the middle of each rib, a bony process issues, which is directed backwards, its end resting upon the preceding rib. There is thus a system of provisions for the firmness of the bony cage formed by the ribs, not only at both extremities of each rib, but also in the centre.

That the object to be attained by the keel erected along the middle of the breast-bone is to strengthen the trunk, so as to resist the action of the wings, is conclusively proved by the fact that with the ostrich and cassowary, which do not fly, there is no such keel.

165. **The Clavicles.**—There are, however, other modifications in the skeleton of the bird which must be regarded as forming accessories to the machinery of flight, that cannot be passed without notice.

It will be remembered that, in the human skeleton, the shoulders are kept apart by the clavicles, or collar-bones, which extend between them and the top of the breast-bone. But if the arms and hands, instead of being instruments of prehension, were organs of flight, the collar-bones, or clavicles, would be utterly insufficient to resist the reaction on the shoulders ; they would soon give way, the shoulders being dislocated and the wings disabled. In birds, therefore, the corner of the scapula, with which the wing is articulated, is connected with the breast-bone, not by one, but by two collar-bones, which, diverging at an angle, divide the reaction of the wing between two extreme corners of the sternum, giving the same

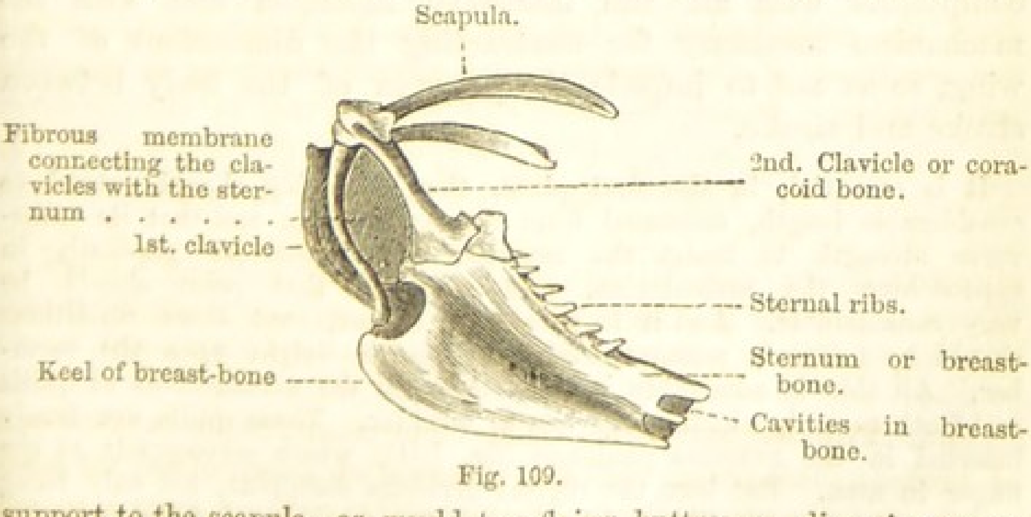


Fig. 109.

support to the scapula, as would two flying buttresses, diverging at an

angle of 45° from the corner of the structure which they are designed to support. To render this more clear, we have represented in fig. 109 the bones here referred to. It will be seen that the scapulæ which in man are tabular, are here long bones, which are parallel to the spinal column. The first clavicles on both sides approaching each other downwards are united at their lower extremities with the front of the keel of the breast-bone. These two clavicles, therefore, looked at from the front, have the form of the letter V, the coracoid bones forming flying buttresses, which, together with the diverging sides of the V, keep the shoulders apart, and supply to the wings solid and firm points of support. That the purposes designed by Nature in this mechanism are those here indicated, is proved by the fact, that in birds which fly but little, or not at all, the clavicles and coracoid bones are only feebly developed. Thus, in certain parrots of Australasia, these bones are altogether rudimentary. In ostriches and cassowaries they are generally, either small, or represented by a mere stylet, or point of bone. In fine, in certain owls, which fly but little, they are connected by cartilage.

166. **The Wings.**—The power of flight depends, not only on the skeleton of the member, and the muscle which moves it, but also upon the extent of surface which is available for the displacement of the air. It will be remembered as we have already explained that, other things being the same, the power of propulsion will depend upon the volume of air displaced by the wing ; and it is obvious that this volume will itself depend on and be proportionate to the superficial magnitude of the expanded wing. But great superficial magnitude in such an instrument would, unless expedients were provided against it, infer corresponding bulk and weight ; and such bulk and weight would operate with proportional force against the ascent of the animal.

Expedients are provided, nevertheless, by which great expansion of the wing and great power of resistance are rendered compatible with all the necessary lightness and with the mechanism necessary for contracting the dimensions of the wing, so as not to impede the progress of the body between stroke and stroke.

It is essential, in the first place, that the wing should extend to considerable length, measured from its articulation, and that its transverse strength to resist the reaction should increase gradually in approaching the articulation, and near to that point should be very considerable. And it is necessary, in fine, that these conditions should be fulfilled, without conferring undue weight upon the member. All this is admirably accomplished by the arrangement of quills and feathers with which every one is familiar. These quills are firmly inserted in the extreme phalange (fig. 104), which corresponds to the finger in man. But here the digital divisions disappear, not only being useless, but incompatible with the solidity necessary for the insertion

of the quills ; and the hand is reduced to a sort of flat and unarticulated stump. It is, however, in the structure of the quills, that the design of Nature is rendered most beautifully manifest. It is demonstrated in mechanics, that to render a rod most powerful to resist a transverse strain, without giving it undue weight, it should receive the shape of a hollow tube, the materials being as dense and compact as possible. Nature has, accordingly given this form to the part of the feather in the wing which requires most strength. At a certain distance from the articulation, the tube becomes a thinner rod, not hollow, or round, but square in its section, and filled with a sort of light pulpy matter, from either side of which issues a range of light feathers of beautiful microscopic structure, each of which has a certain power of resistance relatively to its size. These feathers are ranged side by side along the wing, increasing in length as they approach its extremity, so that the expanded wing has greater magnitude there, where magnitude has greatest mechanical effect (fig. 110).

Fig. 110.

FEATHERS OF THE FORE-ARM.

167. **Their Action.**—The articulations of the wing and connection of the feathers are such that, by its muscular power, the bird, after expanding and making a stroke with it, can draw it back in such a position as to present only its edge to the air, and thus in advancing to displace the smallest possible quantity of air, and therefore to produce the smallest amount of resistance.

In commencing its flight, it is first necessary to raise the body from the ground upwards, and the strokes of the wing are then nearly vertical, the air being driven more downwards than backwards. But when the desired elevation has been attained, and a progressive flight is required, the strokes of the wing are directed obliquely backwards. Nevertheless, as it is still necessary that the weight of the bird should be supported, the stroke of the wing can never be directly backwards, but must be oblique, with just so much of a downward direction as is necessary to balance the tendency of the body to fall by its weight.

168. To give effect to the action of the wings in flight, it is necessary to keep the centre of gravity of the body nearly under the point connecting the articulations of the wings, the axis of the trunk being horizontal. The form of the body of the bird is adapted to produce this effect ; and by presenting its head forward, which it always does in flight, this position of the centre of gravity is further secured, and at the same time

the resistance which would attend a different position of the head is avoided.

It is evident that the power of flight, other things being the same, will be proportional to the magnitude of the wings; and it is accordingly found, that all birds remarkable for rapid and long continued flight have large wings, while those whose wings are short relatively to the volume of their bodies, are

Fig. 111. (R. An.)
THE YELLOW VULTURE.

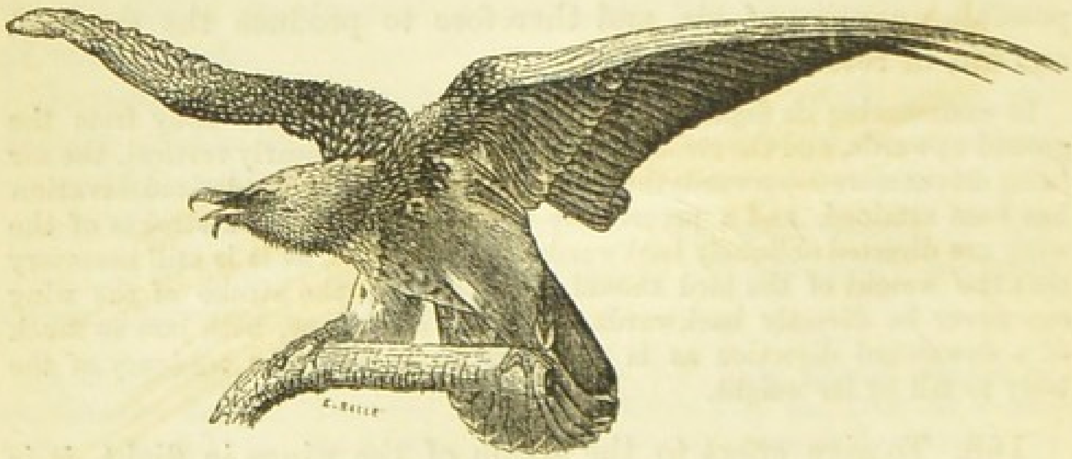


Fig. 112. (R. An.)
THE LAMB VULTURE (Gypactus Barbatus).

less swift of flight and require more frequent intervals of repose.

169. The birds most remarkable for flight, and consequently for the magnitude of their wings in proportion to their volume,

include different species of vultures, eagles, and the frigate-bird.

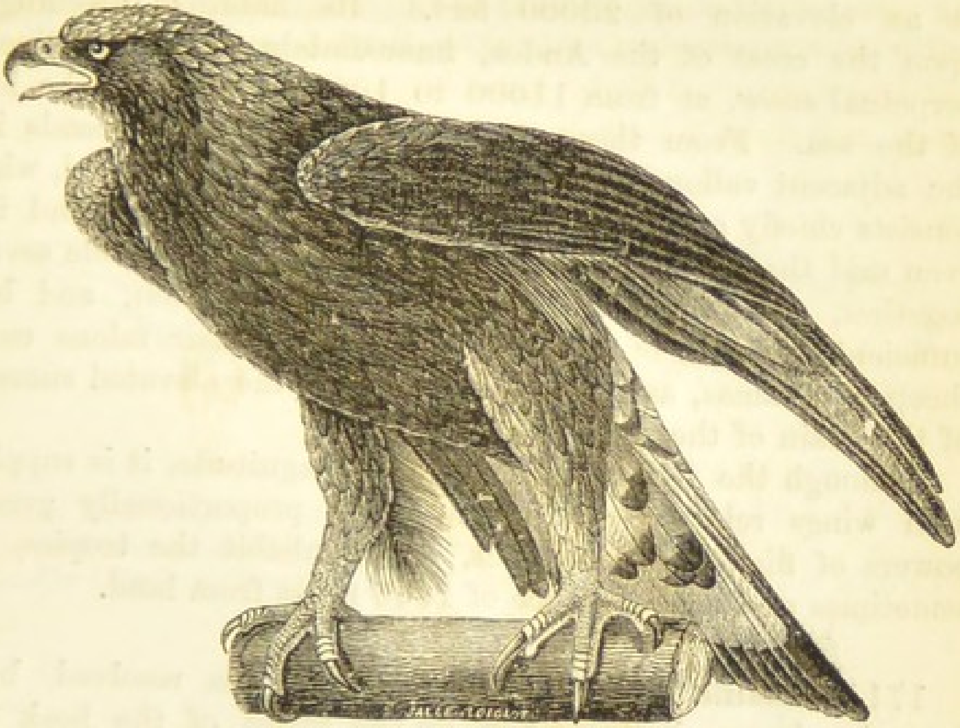


Fig. 113. (R. An.)
THE ROYAL EAGLE.

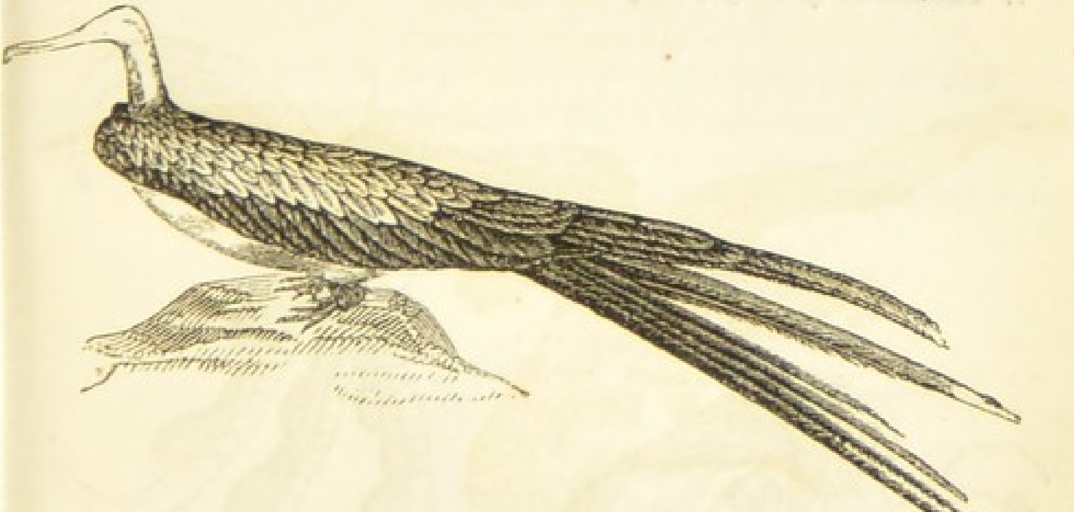


Fig. 114. (R. An.)
THE FRIGATE-BIRD.

170. **The Condor**, or great vulture of the Andes, has wings which, expanded, measure from point to point about fourteen

feet. It rises into more elevated regions of the air than any other known bird; sometimes at the level of the sea, it is seen at others floating above the summit of the Chimborazo at an elevation of 23000 feet. Its habitual dwelling is upon the crest of the Andes, immediately below the line of perpetual snow, at from 11000 to 16000 feet above the level of the sea. From these precipitous summits, it descends into the adjacent valleys and upon the plains to seek its food, which consists chiefly of the carcases of the large animals; and it is even said that these enormous birds sometimes assemble several together, attack and kill animals, such as oxen, and have sufficient strength of wing to carry off in their talons entire sheep and lamas, and transport them to the elevated summits of the chain of the Andes.

Although the frigate bird is less in magnitude, it is supplied with wings relatively larger, and has proportionally greater powers of flight. These birds, which inhabit the tropics, are sometimes seen at a distance of 1600 miles from land.

171. **Classification of Birds.**—Cuvier has resolved birds into six classes, distinguished by the forms of the beak and claws, as follows:—

1. *The Birds of Prey* (Accipitres, Linn.): of which the beak is hooked,

Fig. 115. (R. An.)

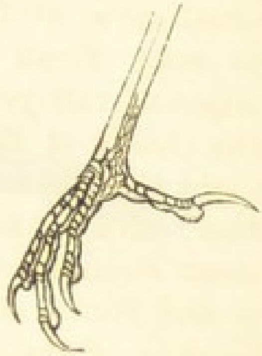
Fig. 116. (R. An.)

the nostrils being pierced through a membrane which covers the entire base

of the beak. The feet are supplied with strong claws ; most of these have a short web between the external phalanges. Fig. 115 represents the head and beak, and fig. 116 the claws, of the falcon (Falco biarmicus).

2. *The Passerine Birds* (Passeres) include more species than all the other families together, and vary much, both in magnitude and power. The two external phalanges are united at their base, and sometimes throughout

Fig. 117. (R. An.)



Fig, 118. (R. An.)

a part of their length. Fig. 117 represents the head, and fig. 118 the foot, of the white-breasted thrush (Turdus torquatus).

3. *The Climbers* (Scansores) are distinguished by the feet, of which two

Fig. 119. (R. An.)

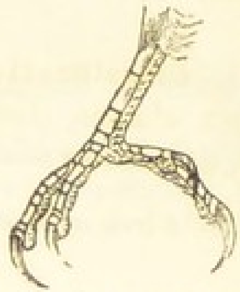


Fig. 120. (R. An.)

phalanges are directed backwards. Fig. 119 represents the head, and fig. 120 the foot, of the Cape woodpecker (Picus capensis).

4. *The Gallinaceous Birds* (Gallinæ): of which the domestic cock is the

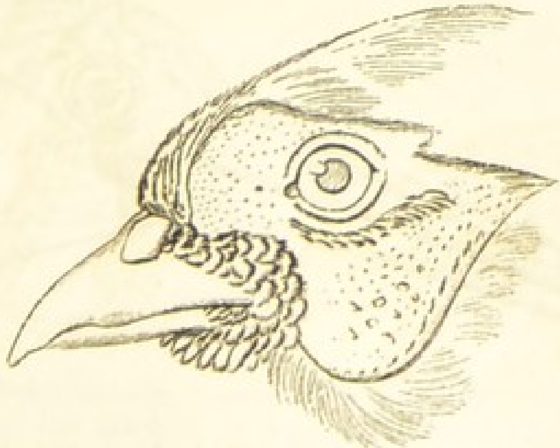


Fig. 121. (R. An.)

type. The head is heavy, the flight imperfect and short, the beak of

moderate size, the upper mandible being slightly bent. The nostrils are partly covered by a soft scale, and the phalanges dentilated at the edges,

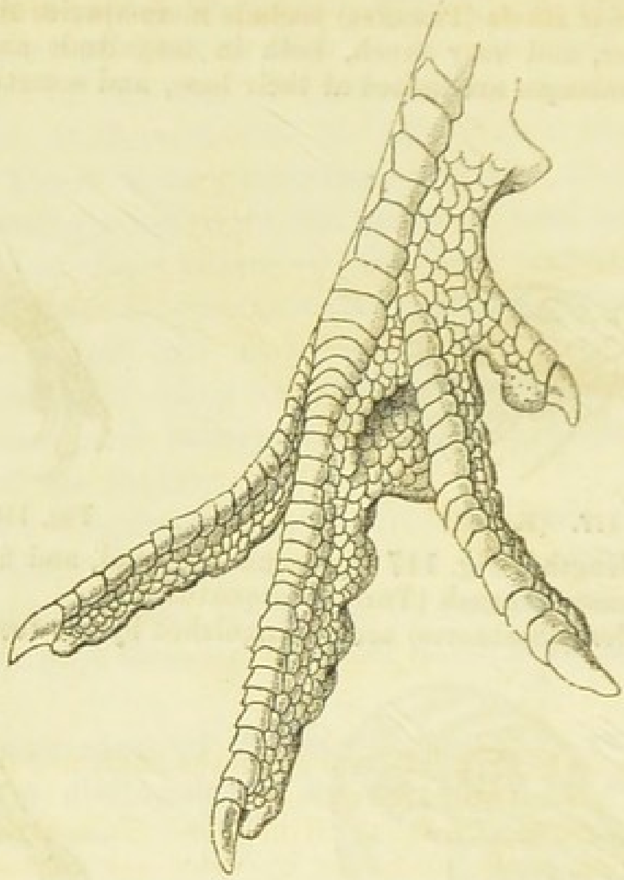


Fig. 122. (R. An.)

having short webs between the bases of the front ones. Fig. 121 represents the head, and fig. 122 the foot, of the common pheasant (Phasianus colchicus).

5. *The Waders* (Grallæ, Linn.), which inhabit the banks of streams

Fig. 123. (R. An.)

and the shores of lakes and seas, have generally a small extent of web

between the phalanges, especially the two external ones. The tarsi are long, the legs denuded of feathers towards the base, and the body slender. In short, the form and structure of the bird is in every respect adapted to facilitate its characteristic locomotion, of wading through the water

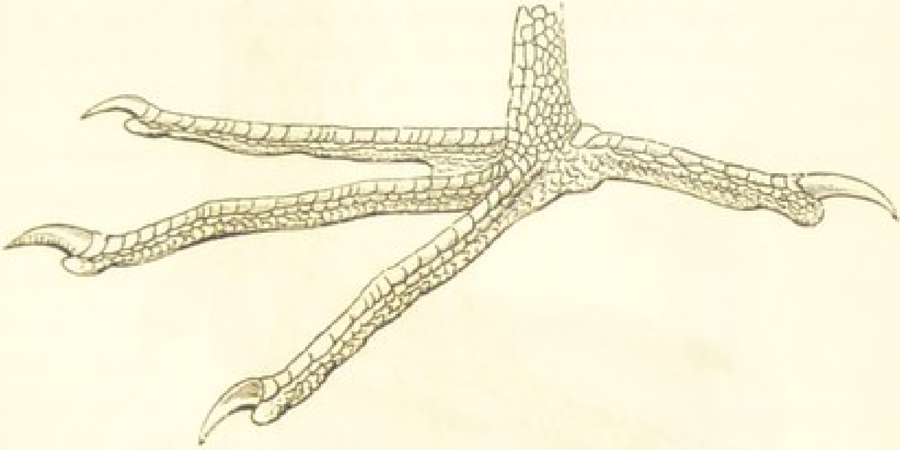


Fig. 124. (R. An.)

in search of its food. Fig. 123 represents the head, and fig. 124 the foot, of a species of heron (Ardea cœrulescens).

6. *The Web-footed Birds*, or *Water-fowl* (Palmipedes), besides the complete junction of the phalanges by webs, are characterised by the backward position of the legs, the length of the sternum and of the neck,

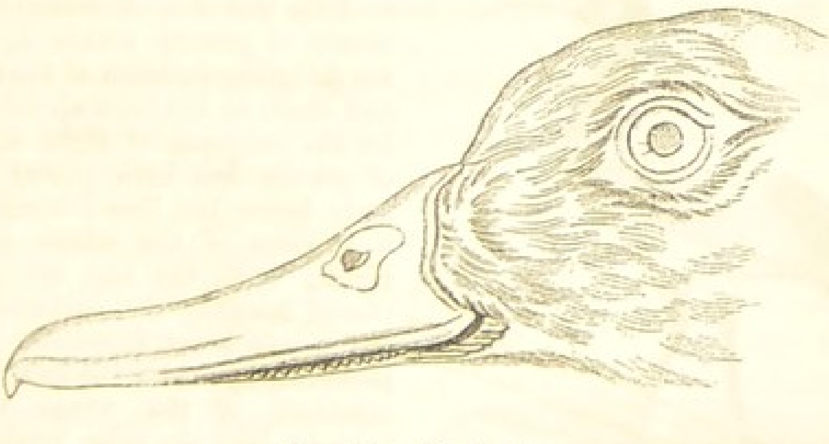


Fig. 125. (R. An.)

and close, polished plumage, impermeable by water. Fig. 125 represents the head, and fig. 126 the foot, of the common duck (Anas boschas).

172. **The Legs and Feet.**—Birds not being always on the

wing, and, when not so, becoming biped, nature has adapted

Fig. 126. (R. An.)

the structure of their legs and feet to the exigencies of their mode of life.

In standing, a base of sustentation must be given to them of sufficient magnitude, and in such a position, as to keep the line of direction of the centre of gravity within it, without too fatiguing exertion of the muscles; and since, as has been already shown, for the purposes of flight the centre of gravity has been placed immediately below the line joining the articulations of the wings with the trunk, while the legs are generally placed towards the posterior part of the body, some expedient must be provided, by which the feet and articulations of the wings may be brought into the same vertical plane when the animal stands. This is accomplished, partly by giving the leg such a structure that the tarsal bones, which extend from the foot to the body, have a sufficient length, and are inclined to the tibia or leg-bones (figs. 103, 104), so as to direct the foot forwards; while the body, on the other hand, assumes such a position, that the spinal column is inclined

Fig. 127. (R. An.)

THE IBIS.

more or less upwards. The flexibility of the neck, which enables the animal to throw the head more or less backwards, aids in bringing the centre of gravity into the desired position, as shown in fig. 127 ; which represents the ibis. In the position of the bird here shown, the centre of gravity is thrown a little behind the line of articulation of the wings, and, therefore nearer the centre of the base of sustentation, by the backward position given to the head. When the animal flies, however, the feet are drawn up towards the breast, and the neck and head extended forwards in the direction of the spinal column, by which the centre of gravity is thrown forward, so as to come in to the position required for flight.

173. **Standing.**—In the case of birds, such, for example, as the penguin (fig. 128), having a short and nearly inflexible neck, and legs which are incapable of being advanced in the manner here described, the animal, when it stands, is obliged to assume the vertical position.

Fig. 128. (R. An.)
THE PENGUIN.

174. **The Claws.**—In giving birds the power of flight, nature would only have done half her work if she did not at the same time so modify the mechanism of their feet as to enable them to rest with security upon the lofty branches of the trees to which their wings transport them. We find, accordingly, that the conformation of the foot is beautifully adapted to this purpose, and thus that the usual harmony and unity of design is manifested here, as in other parts of the animal kingdom.

It has been already explained that the bone of the leg, extending upwards from the foot towards the body, is not, as might at first be supposed, the analogue of the human leg between the knee and the ankle, but the tarsus here reduced to a single bone of vastly greater proportional length than in the human foot, and having a position nearly vertical, instead of one nearly horizontal. The analogues of the toes articulated with the lower extremity of this tarsal bone are the claws, the number of which is usually four, corresponding to the thumb and three fingers, or the great toe and three lesser toes. In most cases, the first is presented backwards, and the other three forwards (figs. 116, 118, 122,

124, 126). The number of phalanges or joints in these toes is different; the thumb or backward toe having only two, and the number increasing from toe to toe, being five in the outward one. But these arrangements are subject to variation in different species, according to the exigencies of their habits and mode of life.

In all cases, however, of birds which are endowed with powers of flight, the claws are so articulated as to give them such flexibility that they can grasp firmly the branch upon which they perch, without extraordinary effort, and cling to it with such tenacity, that even when it is swayed to and fro by the wind, the bird will hold its position with perfect security.

175. **Perching.**—It is further worthy of remark, that this strong hold of the bird in perching is produced without any fatiguing exertion of the muscles. The muscles which move the claws have tendons, which, passing along the tarsal bone, are connected with the extensor muscles of the upper articulation of the leg; and when the bird perches, the weight of its body alone, acting on the flexor muscles of the claws, reacts through the tendons of these upon the extensor muscles of the upper part of the leg; so that the body is kept from sinking upon the legs, not only without any fatiguing exertion of the extensor muscles, but without any exertion of them whatever. Consequently, we see the bird rest upon a movable perch with as much security when it sleeps as when it wakes.

Fig. 129. R. An.)
THE STORK.

176. **Standing on one leg.**—In the structure of the legs of some species, such, for example, as the stork (fig. 129), a mechanical provision is made by which it can rest with perfect security and stability, and without any muscular exertion whatever, and even sleep, on one leg. The lower extremity of

the thigh bone, in such cases, presents downwards a deep cavity, into which, when the leg is extended vertically, a projection upon the upper end of the tibia enters, so as to form a stiff joint. The two parts of the leg, in this position, form a sort of vertical post, on the summit of which the body of the bird is placed, and the centre of gravity is brought over the base of sustentation formed by the line joining the extremities of the claws, partly by the power of the bird to incline its body upwards, and partly by the flexibility of its neck, by which the head can be thrown backwards. The bird rests in this position without any continued action of the extensor muscles ; and when it desires to resume the position suitable for walking, the articulation of the leg, thus rendered temporarily stiff, is restored to its flexibility by a muscular action upon the bones thus connected in the manner above described.

Fig. 130. (R. An.)
THE PARROT.

Fig. 131. (R. An.)
THE WOODPECKER.

177. **Climbers.**—In general, the distribution of the four

claws of perching birds is as described above, three forwards and one backwards; but in species whose habits lead them to practise the action of climbing, such as parrots (fig. 130), toucans, and woodpeckers (fig. 131), they are differently distributed, the first and fourth being turned backwards (fig. 120).

178. **Birds that do not fly.**—That the peculiar structure of the foot just explained is designed by nature to confer upon the animal functions complementary to and concomitant with those of the wings, is proved by the fact that in species like the partridge (fig. 132), which have very imperfect powers of flight, and which do not perch at all, the number of claws are reduced to three, which have little flexibility, the fourth being rudimentary; and in species such as the cassowary (fig. 108), and the ostrich (fig. 133), which have no powers of flight at

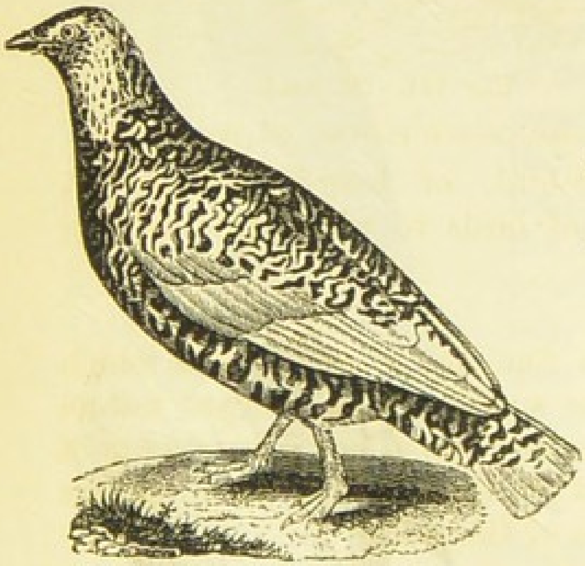


Fig. 132. (R. An.)
THE SNOWY PARTRIDGE.

Fig. 133. (R. An.)
THE AFRICAN OSTRICH.

all, but, on the contrary, can run with the swiftness of a horse, the claws are reduced to two, the third being rudimentary. The same conformation is observable in the locomotive apparatus of the bird called the serpent-eater, which requires great swiftness of foot to pursue its prey. In the case of certain birds of prey, the claws are used for prehension as well as for

support, and are accordingly constructed with a strength proportionate to the magnitude and weight of the objects of prey which they have to lift into the air, as in the example of eagles and vultures (figs. 111, 112, 113, 116).

179. **Waders.**—Birds which live upon the banks of rivers and lakes, or the shores of the sea, and which feed upon worms and the smaller species of fish found there, holding a place intermediate between land and aquatic birds, though unprovided with any apparatus to enable them to swim, have nevertheless a length of leg sufficiently great to enable them to wade in the water in search of their prey, and a length of bill sufficiently great to enable them to seize it. An example of these is presented by the stilt-bird, or long-legged plover, shown in fig. 134. The class of birds to which this belongs is denominated the waders.

Fig. 134. (R. An.)

THE LONG-LEGGED PLOVER, OR STILT-BIRD.

180. **Web-footed Birds.**—In fine, the class of birds which find their food floating near the surface of the deeper waters are supplied with legs, which are very imperfect instruments of locomotion on land, but perfect in their action as propellers when they float upon the surface of the water.

The legs in this case are short. Powerful extensor muscles, having their origin in the upper part of the leg, act upon the claws, so as to drive them backwards, extending them in the direction of the leg, and at the same time inclining the leg more or less backwards ; and, consequently, acting upon the water like an oar or paddle. When the leg is carried forwards, previously to another stroke, flexor muscles bring together the claws, the intermediate web being collected into folds, and other flexor muscles, bending the leg upon its upper articulation, carry it forward, the claws during this motion being held together, and the web being still folded, so as to offer little resisting surface to the water. Previously to recommencing another stroke, one set

of muscles separate the claws, extending the web slightly between them, after which, the extensor muscle of the legs straighten it, throwing the foot at the same time backwards. And by the constant repetition of this action

Fig. 135. (R. An.)
THE KING DUCK.

Fig. 136. (R. An.)
THE EIDER DUCK.

with both feet, the bird is propelled forward on the water. All species of water-fowl, such as geese, ducks, swans (figs. 135 and 136), are examples of this.

181. **Prehensile Organs of Birds.**—The principal and generally the only organ of prehension of birds is the beak, the larger birds of prey using occasionally for this purpose the talons. The form of the beak is as various as the qualities of the substances used as food ; and so close and invariable is this relation between the mechanical structure of the instrument of prehension and the aliment, that a practised naturalist can infer the one from the other with unerring certainty. Thus the fossil beak of an extinct bird informs us of its habits, and structure, in the same manner and by the same analogies as does the tooth of a mammifer.

The bill, or beak, forming the mouth of a bird, consists of a solid, horny substance, sharp at its edges, and variously formed at its extremities. As the mouth is never supplied with teeth, the food undergoes no process of mastication. With carnivorous birds, which have need of tearing their prey, such as hawks, eagles, and vultures (figs. 111, 112, 113, 115, 137), the upper mandible is very short, strong, hooked at the end, and terminated in a sharp point ; sometimes its edges are more or less dentilated, which renders it a more powerful arm of attack ; and the habitudes, more or less sanguinary, of the species may be inferred as these several characters are more or less pronounced in the beak. Thus, the falcon (fig. 137) is, of all birds of prey, that whose beak is shortest, most curved, most

Fig. 137. (R. An.) THE HEAD OF THE FALCON.

Fig. 138. (R. An.)
THE GOSHAWK.

completely dentilated, and, in proportion to its general bulk, most robust.

182. **Goshawk.**—According as species become less fierce, these characters in the structure of the beak are more subdued. Thus the goshawk (fig. 138), a bird of ignoble prey, has its beak curved from its base, its wing shorter than its tail, its tarsi long, and its claws curved and sharp.

Its flight is rapid but low, and it pounces obliquely upon its prey, sometimes pursuing it in flight.

183. **The Kite**, which differs so little in its general form from the falcon, has a beak more feeble, less hooked, and not at all dentilated at the edges.

Another variety, the kite of Carolina (fig. 139), called by naturalists Elamus, has the same characters, but is distinguished by the legs being half-covered with feathers. We find accordingly, as indicated by the beak, that these species are much less fierce than the falcon.

Fig. 139. (R. An.)

THE KITE OF CAROLINA.

The vulture (fig. 111), whose beak, though more hooked than that of the falcon, is longer and consequently weaker, never attacks living prey, feeding exclusively on carrion.

184. **Sea-Birds**, which feed on fish too large to be swallowed at a mouthful, are furnished with a large beak, hooked at the end (fig. 125). But this instrument is much longer, and there-

fore less powerful, though sufficiently so relatively to their prey.

When piscivorous birds feed on such fishes and reptiles as are small enough to be seized and easily swallowed, the beak is straight, still greater in length, and resembling a pair of long pincers, of which those of the martin pecker (fig. 140) and stork (fig. 129) are examples.

185. **Insectivorous Birds**, such for example as the bee-eater (fig. 141), have slender and very long beaks, either straight or very slightly hooked, except when they catch their prey in

Fig. 140. (R. An.)
THE MARTIN PECKER.

Fig. 141. (R. An.)
THE BEE-EATER.

flight, as do the swallow and the goatsucker (fig. 142), for example, in which the bill is short, broad, and deeply cut, so as to enable them to present a large mouth to receive their prey.

Fig. 142. (R. An.
THE GOATSUCKER.

Fig. 143. (R. An.)
THE SPARROW.

186. **Granivorous Birds**, on the contrary, such as the sparrow (fig. 143), have a short thick bill, convex above, or conical, and in general straight, the upper mandible not projecting over the lower.

187. **Pelican.**—A singular modification of this organ of prehension is presented in the case of the pelican (fig. 144), which

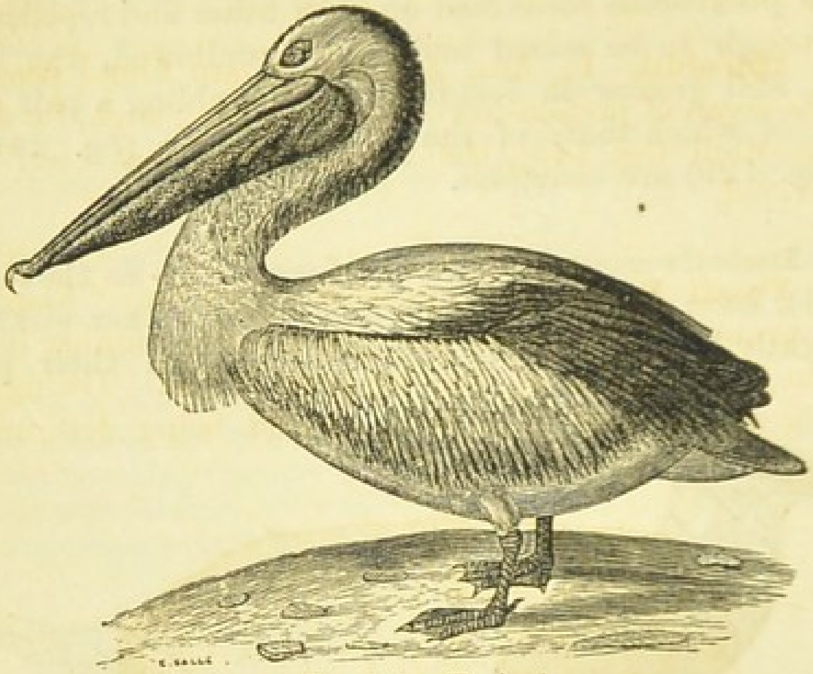


Fig. 144. (R. An.)
THE PELICAN.

Fig. 145. (R. An.)
THE HORNBILL.

has a membranous receptacle, consisting of a cutaneous pocket

or bag, attached to its lower mandible, in which it collects its prey, which it swallows afterwards at leisure.

188. **Hornbill.**—In fine, appendages are found occasionally upon the organ of prehension of certain birds ; such, for example, as the hornbill (fig. 145), the use of which has been hitherto undiscovered.

189. **Fossil Birds**, like mammifers, are only* found in the tertiary group, and there increase gradually in number in ascending from the inferior to the superior strata. Owing to the orders in which birds have been classed being determined by

Fig. 146. (R. An.)
FOOT-PRINTS, AND MARKS OF RAIN-DROPS.

the bills and claws, which are scarcely ever preserved in the fossil state, the classification of fossil birds has presented

* As in the cases of mammifers, some traces have been found in the lower groups, consisting, however, of foot-prints.

more difficulty than has been encountered in mammifers, the orders and genera of which are determined by the bones.

Nevertheless, the inquiry has been facilitated by the foot-prints which, in many cases, have been found in rocks which received them in the soft state, and were subsequently solidified without losing them. In fig. 146, the imprint of the three fore phalanges are shown, accompanied by the curious incidental impressions of rain-drops which happened to fall at the

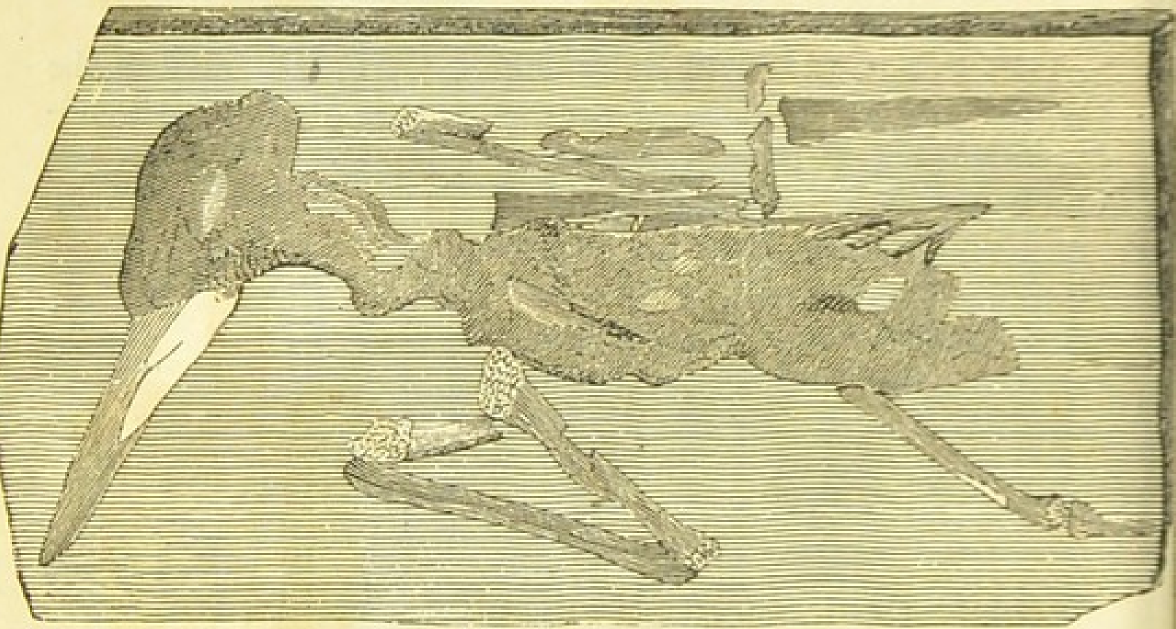


Fig. 147. (R. An.)
FOSSIL BIRD FOUND IN THE GYPSUM OF MONTMARTRE, PARIS.

same moment. In fig. 147 is a mould of the chief parts of a skeleton, including the beak.

The gradual increase of birds with the succession of geological periods is shown by the fact, that while only 11 genera have been found in the lower strata of the tertiary rocks, 29 have been found in the upper strata, the existing genera amounting to about 300, which include above 5000 species.

The foot-prints which have been observed generally consist of three front phalanges, and sometimes of one posterior. The succession of impressions shows the animal to be biped. The magnitude of the feet and the length of the steps, sometimes enormous, prove the existence of birds in these geological epochs, of vastly greater magnitude than any of the existing specimens of the class. In one case, the foot-prints are 15 inches in length and 10 inches in breadth, without counting the posterior phalange, which measured two inches. The length of the steps were from four to five feet, while those of the ostrich are seldom so much as a foot.

REPTILES.

190. **Form and Structure.**—The animals assigned by natu-

ralists to this class differ one from another extremely in their

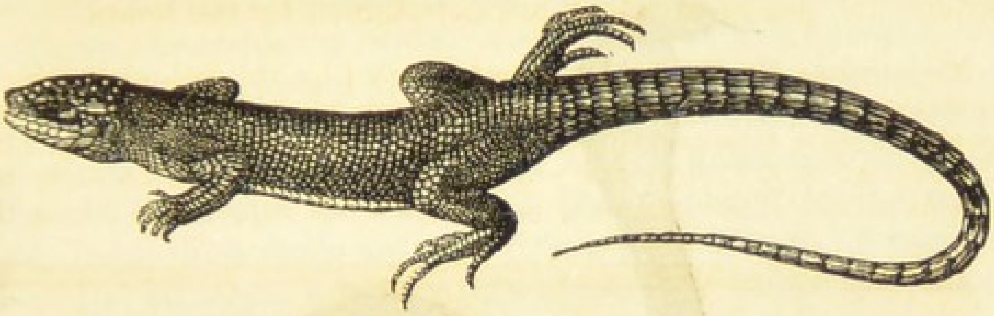


Fig. 148. (R. An.)
THE GREEN LIZARD.

form and structure, as may be imagined when it is stated that they comprise species so very unlike as tortoises and serpents. The characters by which the class is zoologically distinguished have reference to their circulating apparatus and to the physical condition of their blood, as will be explained in a succeeding chapter.

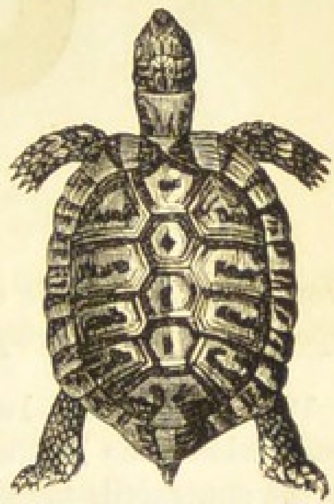


Fig .149. (R. An.)
THE GREEK TORTOISE.

The head of the reptile is small, and the body generally, but not always, long in proportion to its diameter. Some species, such as tortoises (fig. 149), lizards (fig. 148), and frogs, have four legs, the feet of which are formed for moving either on the ground or through the water.

In some species the legs are merely rudimentary (fig. 150); and in others, such as serpents (fig. 151), they are altogether wanting.

The legs in such species as possess them are always so short,

Fig. 150. (R. An.)
CHALEIS.

and their action so nearly lateral, that they supply very imper-

fect instruments of locomotion, so that the body trails on the

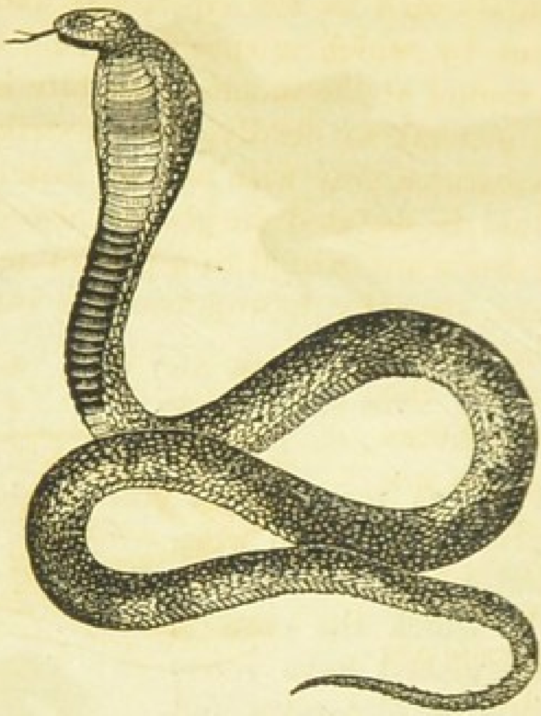


Fig. 151. (R. An.)
RAJA ASPIC.

ground ; whence the class takes its name, from the Latin word *repo*, signifying *I creep*.

191. **Serpents.**—In these species, such as the varieties of serpents where the legs altogether disappear, locomotion is effected by the contractile force of the muscles alternately drawing up and extending the body, combined with the adhesion of the tegumentary covering with the ground. The animal attaching to the ground a point near its head contracts its body, or even bends it into an arch, bringing forward the hinder part, some point of which it then attaches to the ground, liberating at the same time the fore part. The posterior point of attachment then becoming a fixed point, the animal throws forward its length by the action of its extensor muscles, after which it again attaches a point in the foremost part of its body to the ground, and repeats the same process.

The two points thus alternately taken as points of re-action may be close to each other, and other pairs of similar points may be at the same time in operation at other parts of the body. By a series of such points of re-action an animal of this class can give itself a progressive motion by the alternate contraction and extension of its body without arching or elevating any part of it from the ground.

192. **Poisonous Serpents.**—Nature has provided several species of serpents—such as the viper, asp, and rattlesnake—with an apparatus by which a specific poison is secreted, and poured into the wound at the moment the bite is accomplished. This poison is in general so deadly, that it strikes the animals on which these creatures prey with almost instantaneous death. The venomous fluid is secreted in glands placed in the upper jaw, from which ducts are carried to a pair of teeth of peculiar form and structure, specially appropriated to inflict the poisonous bite. The ducts enter the roots of the teeth at the embouchures of perforations which are continued through the teeth, and terminate with openings near the points. The venomous glands are placed in immediate contact with the temporal muscles, so that the same act which moves the jaws in inflicting the bite, compresses the gland, and expels the poison through the duct and the dental canal, so that it is poured into the wound at the moment the tooth pierces the flesh. It is remarkable that this poison, deadly as it is when applied in the manner in which the animal imparts it, is absolutely innocuous if taken into the mouth and stomach. When inflicted by the bite, it is mixed with the blood, and carried by its current through the circulation, where alone it is destructive ; the effect being to retard the circulation, to destroy the coagulability of the blood, and to accelerate the gangrene and mortification in the wounded part.

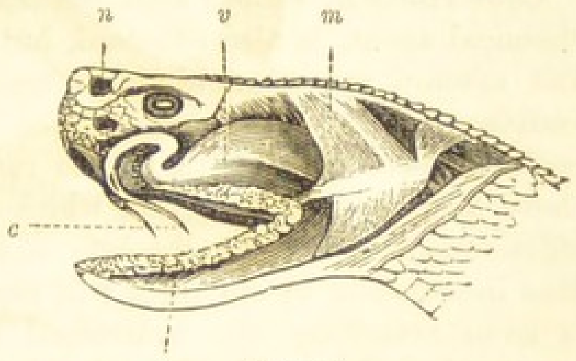


Fig. 152.
MOUTH OF THE RATTLE-SNAKE.

The mouth of the rattle-snake (fig. 153), with its venomous apparatus, is represented in fig. 152, where *v* is the venomous gland, the excreting duct of which terminates in the large moveable tooth *c*. The levator muscles, *m*, of the jaw invest and compress the gland *s*, the salivary glands are disposed along the edges of the jaws, and below *n*, the nostril, appears a second similar opening, by which these and some other serpents are distinguished.

193. **Remedies.**—The most effectual remedy against the consequences of such poisonous bites, is immediately to suspend the local circulation by compressing the veins above

the point attacked—that is to say, between the point and heart—so as to prevent the flow of the poisoned blood into the system, and at the same time to apply suction to the wound either by the mouth, or, still better, by a cupping instrument. That sucking by the mouth may be applied with impunity is proved by the fact already mentioned, that the poison, though destructive when it enters the circulation, is altogether innocuous when it passes through the alimentary canal.

Cauterisation, either with red-hot iron or with any strong chemical agent, is also effectual, but such remedies as ammonia and arsenic are of doubtful efficacy. The South American Indians, who are exposed to the frequent attacks of these reptiles, have great faith in the remedial virtue of a plant of those countries called guaco, which they affirm to be not only efficacious as a cure for the bite of the venomous serpents, but that inoculation by its juice will repel the reptile, and prevent it from attacking the individual thus prepared. It would appear that Humboldt himself did not altogether discredit this popular remedy, and considers it possible, if not probable, that

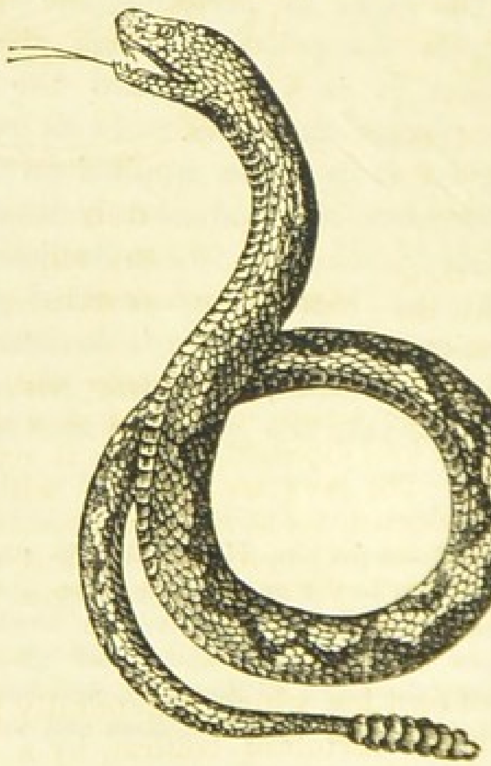


Fig. 153.
THE RATTLE-SNAKE.

the plant may impart an odour to the person inoculated such as to repel the reptile.

194. **The Skeleton of Reptiles** is not so uniformly constructed as that of mammifers. With the exception of the cerebro-spinal column, every part of it is absent in one species or another. When present, however, the various bones constituting it are always analogous to those of birds and mammifers.

The head is small, and the face elongated. Like that of birds, the lower jaw consists of several parts, and is articulated to the temporal bone by one, and sometimes two, intermediate pieces. It is owing to this mechanism that serpents are enabled to open their jaws so widely as to swallow their prey whole, that prey being often larger than their entire body.

The skeleton of the head of the rattlesnake (fig. 153) is shown in fig. 154. A short moveable bone, called the mastoid, D, is articulated to the skull, C, and connected with it by ligaments and muscles. To this another bone B is jointed, and to the lower extremity of the latter the branch of the lower jaw, A, is articulated. The two branches of the lower jaw are not connected. Thus, the utmost freedom of motion is given to this part; and owing to the length of the intermediate bone B, a great capacity is obtained at the interior part of the gullet as well as at the front of the mouth. The branches of the upper jaw are only attached to the intermaxillary bone by ligaments which allow them a certain play, in which the bones of the palate, G G, participate. This structure is in remarkable accordance with the habits of the animal, which engulphs large masses of aliment at a single meal without mastication, during the long digestion of which it remains in a state approaching to torpidity. The jaws are furnished with sharp, hooked teeth, which are however adapted, not at all for mastication, but merely for the seizure and retention of its prey previous to deglutition.

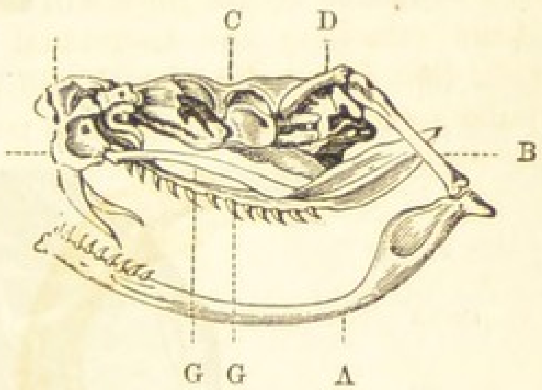


Fig. 154.
SKELETON OF THE HEAD OF A RATTLE-SNAKE.

An increased power is given to the mouth by a certain limited mobility which is allowed to the upper jaw.

195. **The Skull** of reptiles, which is generally fixed, or nearly so, is connected with the vertebral column by a single condyle having several facets.

196. **Trunk.**—In lizards, crocodiles, and reptiles similarly formed, the bones of the trunk present but few anomalies. The ribs are more numerous than in mammifers and birds, being

continued over the lumbar portion of the vertebral column as well as the dorsal. In serpents, the sternum or breast-bone is absent, and all the ribs consequently have the mechanical character of the false ribs in mammifers. Their number is sometimes prodigious. In the adder, for example, there are above three hundred pairs, the mobility of which, combined with that of the vertebræ, has an important share in facilitating the movements of that animal.

197. **Skeleton of the Tortoise.**—One of the most remarkable examples of the expedients by which nature attains her purposes without departing from the general plan which she appears to have prescribed to herself in the construction of the solid

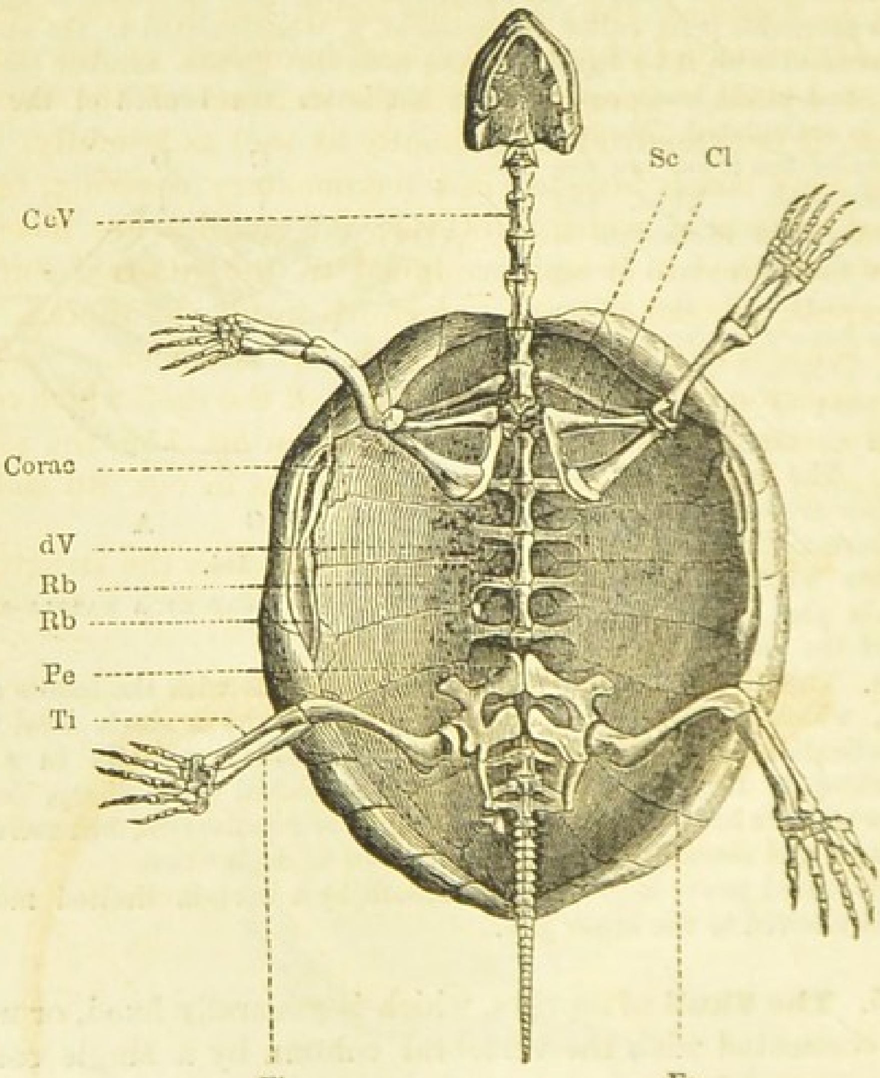


Fig. 155. (R. An.)
SKELETON OF THE TORTOISE.

frame-work of vertebrate animals, is presented in the case of the tortoise, where all the principal parts of the skeleton of the

superior animals can be recognised, though signally changed in their form and proportions.

The tortoise, as is well known, is enclosed between two shells, one of which, the carapace, covers its back, and the other, the plastron or breast-plate, its belly. These two are united at the sides, leaving an opening before and behind, through which the animal can put out its head and fore-legs in front, and its posterior members behind. Now the carapace or shell, which covers the back, is the homologue of the vertebral column and ribs. The ribs are flattened out, and cemented together edge to edge, so as to form a continuous shell. The shell which covers the belly is the analogue of the sternum or breast-bone, and the cartilaginous parts of the ribs, in the superior species. The former is flattened out; and the latter, like the ribs, are also flattened, cemented edge to edge, and hardened to the consistency of a shell. Compared with the sternum of the superior animals, it is extended longitudinally as well as laterally.

This bony box is invested in a tegumentary covering, on the external surface of which, however, no muscles are inserted; all those attached to it being confined to the internal surface. The scapula, instead of being outside, is inside the thorax. The pelvic bones are in like manner within the abdomen.

The skeleton of the tortoise, divested of the shell which covers its belly, and seen from below, is shown in fig. 155, the several parts being indicated by the same letters as in figs. 86 and 92.

198. **Lizards.**—In other reptiles of this class the structure of

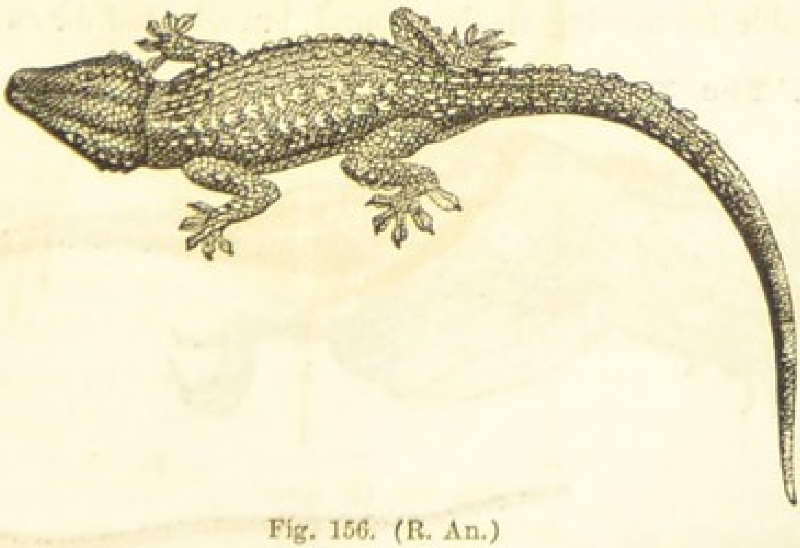


Fig. 156. (R. An.)
THE GECKO.

the shoulder bears a closer resemblance to that of birds. The legs

are sometimes truncated, and, with the land-tortoises (fig. 149), serving merely to push the animal forward. Sometimes they are furnished with nails or claws, by which the animal can hook itself to the inequalities of the ground, and cling to objects in a vertical position as lizards do. Sometimes, as in the case of the wall-lizard, called the Gecko (fig. 156), they have a sort of suckers to their feet, by which they can run up the smoothest walls.

In reptiles which chiefly inhabit the water, such as the sea-

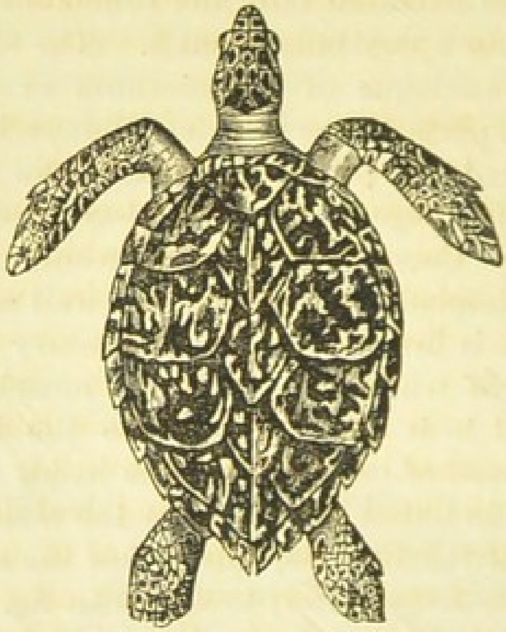


Fig. 157. (R. An.)
THE SEA-TORTOISE.

tortoise, the extremities are formed into a sort of paddle unsuitable for moving on the ground, but adapted for swimming.

199. **The Dragon.**—Among the existing reptiles, there is

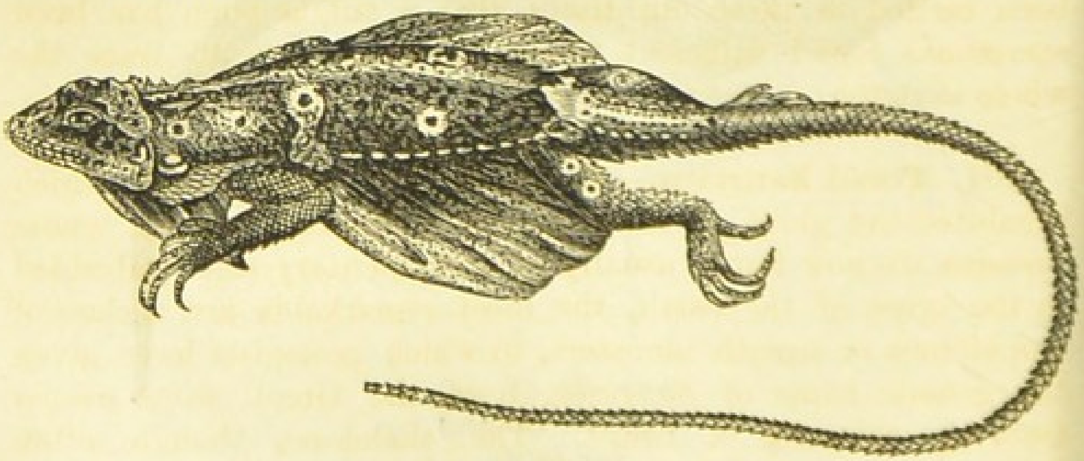


Fig. 158. (R. An.

one called the *dragon* (fig. 158), which combines the powers of

crawling and flying. Resembling in its general form a lizard, or saurian, it is furnished with a web projecting from its sides, like those which form the wings of a bat, but which, instead of being moved by the members, is altogether independent of them, and is sustained by the ribs. The animal does not work this web as birds do their wings, but merely uses it as a parachute to moderate its fall, as it leaps from branch to branch. These singular reptiles, which inhabit India, realise the poetical fiction of flying dragons; with this difference, however, that instead of being formidable by their magnitude and voracity, they are small, and prey only upon insects.

200. **Extinct Reptiles.**—One of the uses of thus tracing the connection between the mechanical structure of the skeleton and the powers of locomotion conferred upon the animal is, that the generalisations which result from such analogies supply means of discovering the functions and habits of animals with whose skeletons alone, or even with certain parts of them only, we are acquainted. Such reasoning has conducted those who have devoted their labours to geological researches to the most surprising discoveries. The skeletons of animals which inhabited the earth and had disappeared from it thousands of ages before the appearance of man upon it, being found imbedded in rocks, have supplied all the data necessary to discover their modes of life, their habits, and the sort of food upon which they subsisted. In some cases, a part only of the bones have been found, which nevertheless the general analogies of structure have rendered sufficient to enable anatomists to infer all those that are deficient; nay, such is the perfection to which comparative anatomy and physiology have been carried in these our times, that a single bone has been sometimes found sufficient to enable anatomists to trace the whole skeleton.

201. **Fossil Saurians.**—Among the monstrous animals which inhabited the globe at these remote geological periods, whose remains are now found usually in a fragmentary state imbedded in the crust of the earth, the most remarkable are a class of amphibious or aquatic monsters, to which geologists have given the generic name of *Saurians*, from the Greek word σαυρος (sauros), meaning a lizard. The skeletons, though often incomplete, nevertheless enable us, by anatomical analogies, to determine the form, dimensions, habits, and modes of life of

these prodigious reptiles. Numerous species have been discovered agreeing in their general resemblance to the crocodile and the lizard; their bodies were covered with scales; they had four members, the phalanges of which were furnished with claws. Their mouths were armed with formidable teeth, and all had a tail of greater or less length. Their general magnitudes far exceeded that of the largest of this class of reptiles at present existing on the earth.

Geologists have distinguished these extinct animals into many species, which they have named either from their magnitudes or their resemblance to known animals. Thus one species, from its vast magnitude, is called the *Megalosaurus*, from the Greek word μεγαλος (megalos), great; another is called the *Ichthyosaurus*, from its resemblance to a fish, the Greek word ἰχθυς (ichthus) signifying a fish; another is called *Plesiosaurus*, from the Greek word πλησιος (plesios), 'next to,' from its close resemblance to the crocodile.

202. **Megalosaurus.**—The most remarkable of the saurians is the Megalosaurus, discovered by Dr. Buckland imbedded in the strata of oolitic slate at Stonesfield, near Oxford. The remains found show that these animals had a form partaking of the structure of the crocodile and monitor, and a length of from forty to fifty feet. The femur and tibia, or thigh and leg bones, which have been found, measure three feet each, and the metatarsal or instep, thirteen inches. The habits of this class of animals and the nature of their food have been generally inferred from the structure of their teeth, which Dr. Buckland describes as consisting of a combination of mechanical contrivances involving at once the principles of the knife, the sabre, and the saw. When first protruded from the gum, the apex of each tooth presented a double-cutting edge of serrated enamel. In this first stage, its position and line of action were nearly vertical; its form resembling 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 to 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.

In a tooth thus formed for cutting along its concave edge each movement of the jaws combined the powers of the knife and saw, whilst the apex, in making the first incision, acted like the two-edged sabre ; the backward curvature of the full-grown teeth enabled them to retain, like barbs, the prey which they had penetrated.*

203. Fossil Reptiles, unlike the superior vertebrates, are found in all the rocks, from those which lie over the Devonian and Silurian groups, to the upper tertiary, which are in immediate juxtaposition with the superficial strata. The remains discovered in all these groups of rocks are not only numerous, but those of individual specimens are found in a state of greater integrity and perfection than those of mammifers or birds, the deficient parts of which are reproduced by osteological analogies. Reptile skeletons, on the contrary, are sometimes found complete, with all their parts in their proper relative position, and even the vestiges of their connecting tendons and of the muscles which gave them motion have been traced. When the entire skeleton is not thus found, the heads, with the vertebral columns, and the component vertebræ are present. Such remains are recovered in great numbers in all the strata from the lowest of the secondary group to the uppermost of the tertiary.

The Chelonians,† or land and sea tortoises, are diffused through all the strata above the trias group.

The Saurians, or crocodile and lizard tribes, are diffused through all the strata above the carboniferous limestone.

Of these, numerous genera existed in the remote geological epochs which have since become extinct, and which have even disappeared in the superior and more modern strata. Thus there are not less than twelve genera of Saurians found in the trias group, and ten in the Jurassic or Oolitic group, which have disappeared from all the more recent formations.

204. **The Ichthyosaurus**, (fig. 159) or fish-lizard, is an example of an extinct animal of this tribe, which has the muzzle and general aspect of a porpoise, the head of a lizard, the teeth of a crocodile, the vertebræ of a fish, the sternum or breast-bone of an ornithorhynchus, and the fins of a whale. The enormous magnitude of the eye-balls was one of the peculiarities of this genus. The cavities in which they were lodged, in one of the species, measured not less than fifteen inches in diameter. The eye-ball was protected by a ring of bony plates resembling those still seen in birds, tortoises, and certain saurians, the use of which was doubtless to push forward or draw backward the cornea, so as to increase or dimi-

* Buckland, Bridgewater Treatise, vol. i. p. 238.

† Χελωνη (chelonè), a tortoise.

nish its radius, and thus vary the range of distinct vision. This, combined with the great power of the fins or propellers, must have conferred upon the reptile great promptitude in perceiving and seizing its prey.

These reptiles were essentially aquatic, and the form of their teeth proves them to have been carnivorous. Their coprolites, or fossilised

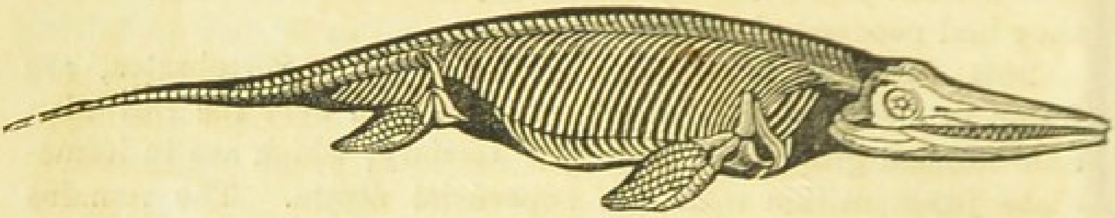


Fig. 159.
THE ICHTHYOSAURUS.

excrements, show that their intestine was spirally arranged, like that of certain fishes.

This genus was most prevalent during the period of the formation of the lias rocks.

205. **The Plesiosaurus,** a reptile closely allied to the lizard tribe, (fig. 160,) had the head of a lizard, a neck of prodigious length, resembling the body of a serpent, the tail of a quadruped, the ribs of a chameleon, and the fins of a whale. This monster of a remote epoch of the globe has been compared to a serpent supplied with the shell of a tortoise. While reptiles in general have but eight cervical vertebræ, this had thirty-three. Mr. Conybeare, to whom its discovery is due, concludes that it was a monster of the deep; that, by the enormous length of its neck, it was enabled to dart upon its prey without moving from its place. These reptiles

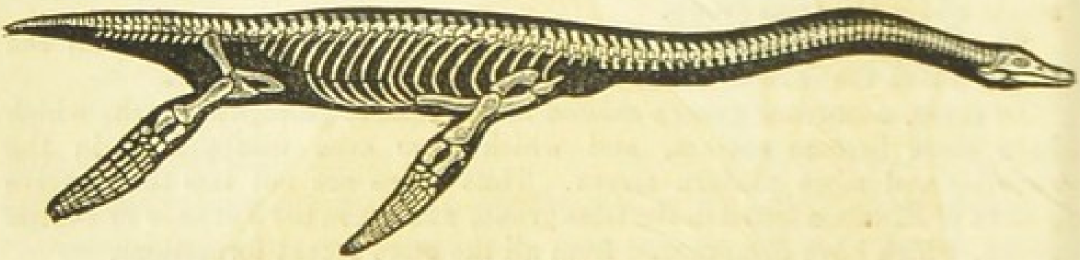


Fig. 160.
THE PLESIOSAURUS.

are first seen in the trias group; they were most numerous at the epoch of the deposition of the lias strata of the Jurassic group, and disappeared at that of the formation of the upper strata of the same group.

206. **The Cetiosaurus,*** or whale-lizard, the discovery of which is due to Professor Owen, is characterised by spongy bones, and the absence of the medullary canal in the long bones. These reptiles had a magnitude equal to that of the largest whales. They first appear in the upper strata of the Jurassic group, but are more numerous in the lower strata of the

* Cetus, a whale.

cretaceous. The only existing genus is the crocodile. The jaw of an alli-

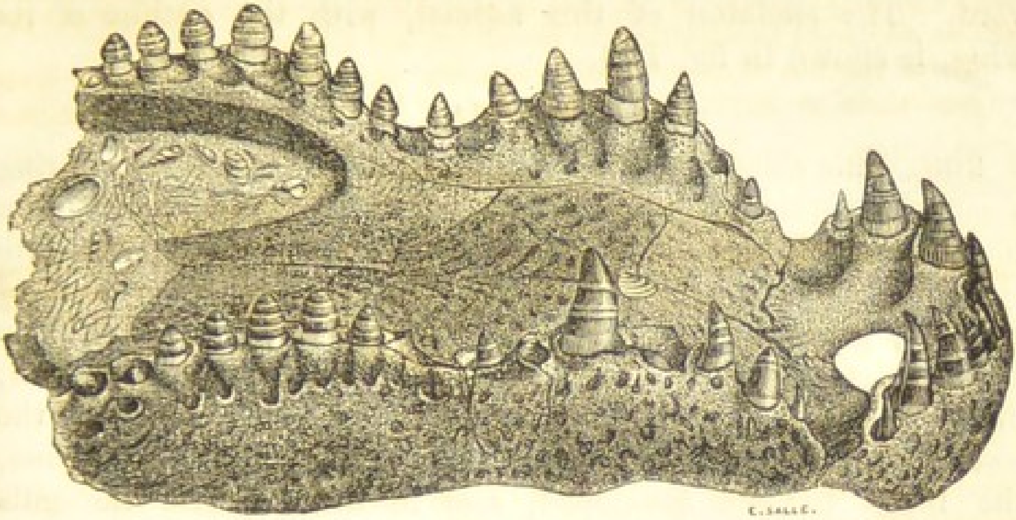


Fig. 161.

gator of this family, found in the tertiary strata of the Isle of Wight, is shown in fig. 161.

207. **Pterodactyle.**—The epoch of the saurians was also signalised by its flying reptiles, on a scale, however, vastly greater than the dragon of the zoologists. Among them was a

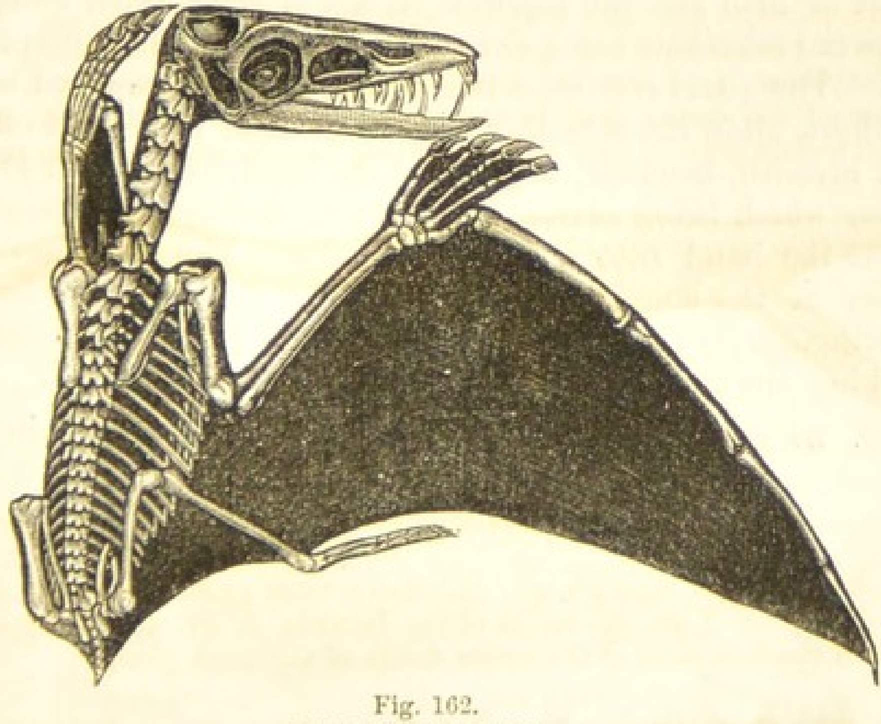


Fig. 162.
THE PTERODACTYLE.

species of gigantic bat, which has received the name of Pterodactyle, from two Greek words, πτερον (pteron), a wing, and δακτυλος (daktulos), a finger; inasmuch as one of the fingers, being of extraordinary length, is supposed to have had an extensive web attached to it, which it extended, in flight, in

the same manner as the sail of a ship is extended upon its yard. The skeleton of this animal, with the outline of its wing, is shown in fig. 162.

AMPHIBIA.

208. This class, as their name implies, is capable, during a certain portion of their existence, of living indifferently on the land or in the water, and therefore hold an intermediate place between reptiles and fishes. During the first period of life they generally dwell altogether in the water, to which alone their structure is then adapted ; their respiration being effected, like that of fishes, by means of gills, which, being washed by the water, take from it the air fixed in it. As the animal grows, the lungs become developed, and in most species the gills gradually disappear. The legs, which are generally absent in the young, are also put forth, and the animal acquires at once powers, though very limited ones, of aërial respiration and locomotion.

The members, constructed in accordance with their habits, are adapted, however, chiefly to aquatic propulsion. As in the cases already noticed, the general plan of the skeleton is conformable to that of man and the superior classes of vertebrated animals, the special functions being obtained by mere modifications of the parts. The parts corresponding to the arm and fore-arm being very short, allow the muscles to act upon them with great effect. Great breadth, however, is given to the hand, and length to the fingers, which being enclosed in a strong and tough membrane, convert the hand into a sort of paddle. The structure and number of the bones correspond to those of the human hand ; and although its external form differs much from that member, a striking similitude will be apparent in the skeleton.

209. **The Seal.***—An example of this is presented in the

Fig. 163. (R. An.)
THE SEAL.

case of the seal, fig. 163, the skeleton of which is shown

* According to some naturalists, Seals, Otters, &c., are not strictly amphibious.

in fig. 164, where the parts corresponding to those of the

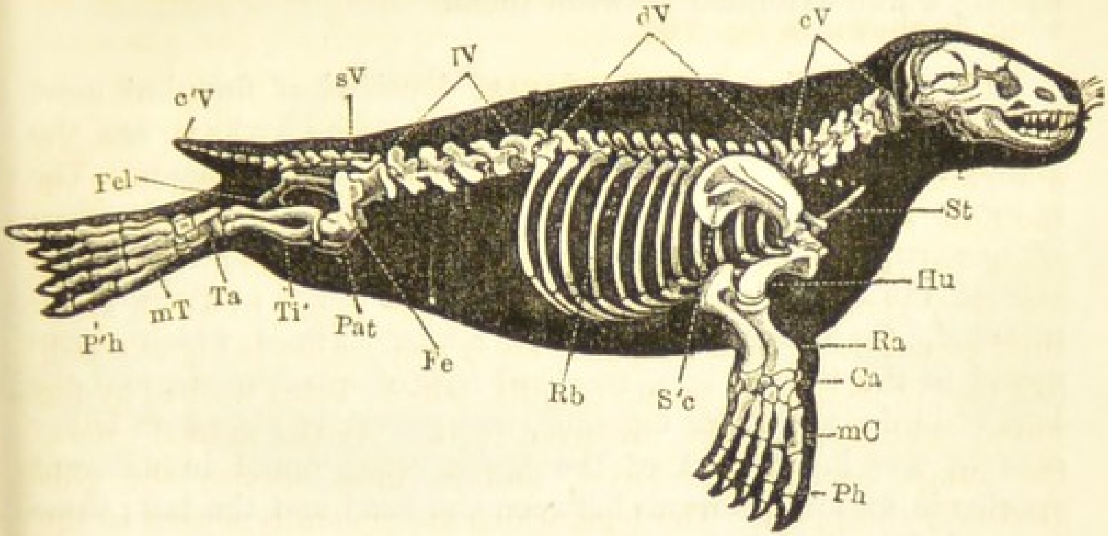


Fig. 164. (R. An.)
SKELETON OF THE SEAL.

human skeleton and that of other vertebrated animals are indicated.

The phalanges of this class differ much in certain species from those of land animals, the number being often very considerable ; and they are sometimes replaced by a multitude of small bony rods connected together by a membrane resembling the fins of fishes.

FISHES.

210. The animals which inhabit exclusively the waters have generally forms peculiarly adapted to move through a liquid. Inequalities such as those which characterise the form of land animals would prove an impediment to their motion ; the head is therefore connected with the body without the intervention of a neck ; nor are there any extensive projecting members to the motion of which the fluid would offer any resistance. The longitudinal section of the body presents a close approximation to the form determined by mathematicians as that of the solid of least resistance—tapering towards the head and tail, and gradually enlarging towards the middle. The skin is smooth but scaly, offering little resistance to friction directed from the head towards the tail, but a considerable resistance in the other direction, owing to the position of the scales. The anterior and posterior members are replaced by fins, the phalanges

consisting of a series of thin bony rods, not articulated, having a web extended between them.

211. **Fins.**—Some few species are deprived of fins, but most species are supplied with these appendages, which are the analogues of the four members of the superior classes. The anterior fins, corresponding to the human arms, the fore legs of quadrupeds, and the wings of birds, are placed at each side of the trunk immediately behind the head, and are denominated, from their position, pectorals. Those which correspond to the human legs, the hind legs of quadrupeds, and the legs of birds, are closer together, and generally placed on either side of the lower part of the body, being found in different species in various positions between the head and the tail; these are called ventral fins.

Other organs of the same form, having no analogues in the superior animals, are found in certain species placed in the median plane on the back or belly, and, unlike the other fins, they exist singly, and not in pairs. These are variously denominated, according to their position, dorsal, anal, and caudal fins.

212. **Gills.**—On either side of the head are openings corresponding with the position of the ears, in which are deposited the gills, which play the part of the lungs, being endowed with the functions of aquatic respiration. The water entering in front, and escaping through these lateral openings, washes the foliated structure of the gills, which absorb the air suspended in it.

213. **Scales.**—The tegumentary covering of the body consists generally of scales of various form and structure, but disposed most commonly one upon the other like the scales of armour, and so lying that, as the animal advances through the water, the pressure of the fluid upon them shall tend to keep them in close contact, and not to enter between scale and scale. These scales are remarkable for their brilliant colours, having generally a metallic lustre, and often reflecting, like mother-o'-pearl or shot-silk, the richest hues, such as greens, blues, reds, purples, and so on.

214. **Skeleton.**—The skeleton of fishes is generally, but not always, osseous ; certain species being exclusively cartilaginous.

The composition of the bones differs from those of mammifers by the absence of gelatine.

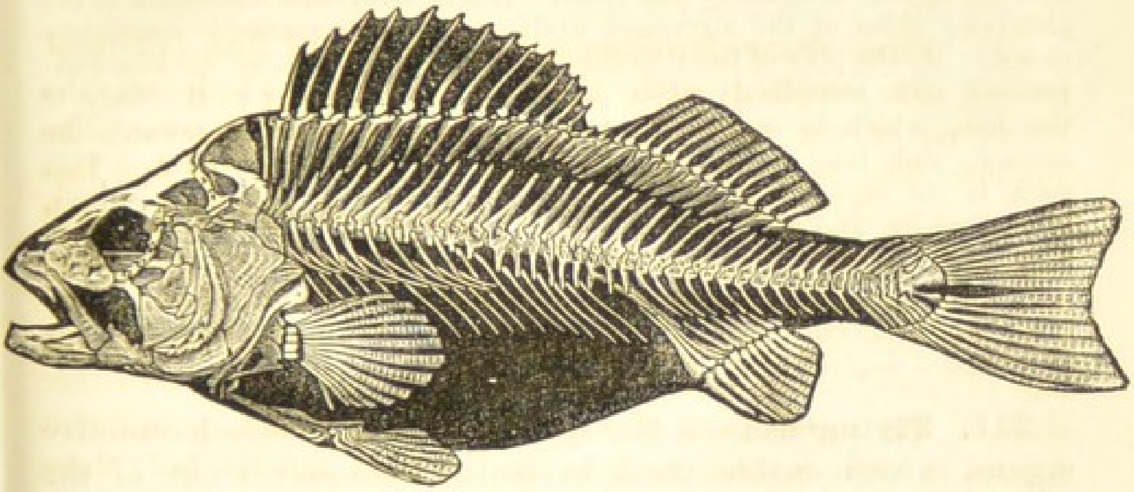


Fig. 165. (R. An.)

The form of the head resembles that of the prow of a vessel. Nature, therefore, appears to have conferred upon them that peculiar configuration which is most favourable to their movement in the element in which they dwell.

215. **Organs of Natation.**—These animals in general swim with great agility. It is said that the salmon, for example, can move through the water at the rate of from twenty to twenty-five miles an hour. They propel themselves through the water by striking that fluid laterally by the alternate inflexion of their trunk and tail, the fins in which the tail terminates acting on the water like an oar in sculling a boat. To confer upon the animal sufficient strength for this important action, it is furnished with powerful muscles by which the lateral flexion of the vertebral column is produced alternately on one side and the other. These muscles are developed to such an extent that they alone form the chief part of the volume of the body. The caudal, dorsal, and ventral fins co-operate in the propulsion to a certain extent, but the lateral ones have no other influence than that of directing the course of the animal, and of maintaining it in equilibrium.

216. **Air-bladders.**—There is a particular organ in fishes called the air-bladder, which has an important share in the powers of aquatic locomotion which this class of animals enjoy.

Placed within the abdomen under the dorsal part of the spinal column, it

communicates in many species with the œsophagus or with the stomach by a canal through which the air contained in it can escape, but in general the air does not appear to enter by this route. It is in most cases a secretion of the glandular sides of the air-vessel itself, which is sometimes completely closed. By the play of the ribs this elastic bladder is more or less compressed, and accordingly gives greater or less buoyancy to the body of the fish, which is enabled by this means at will to rise towards the surface, sink into deeper water, or continue at the same level. That such is its especial purpose is demonstrated by the fact that in rays, soles, turbots, and eels, which remain either at the bottom or buried in mud, this organ is either very small or altogether absent. It is sometimes membranous, receiving numerous capillaries like a lung, which it represents in a rudimentary state, and the functions of which it may possibly to a certain degree be endowed with.

217. **Flying-fish.**—A few species of fishes possess locomotive organs, which enable them to launch themselves out of the water and sustain themselves for a few moments in the air.

The flying-fish (fig. 166) presents an example of this. There are also some which, by creeping and jumping, are enabled to move upon the

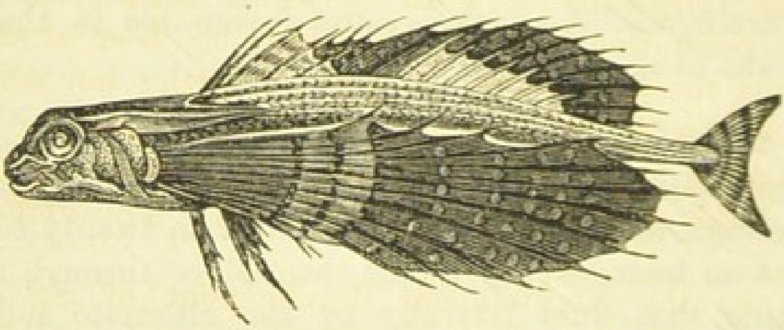


Fig. 166. (R. An.)

ground, and some are even cited which climb up trees; but these examples are extremely rare, and some of them of questionable authenticity.

218. **Sucking-fish.**—Among the prehensile and motor organs of fishes, those by which they are enabled to attach themselves with extraordinary tenacity to external objects, ought not to be omitted.

The Remora (fig. 167), or sucking-fish, which prevails in the Mediterra-

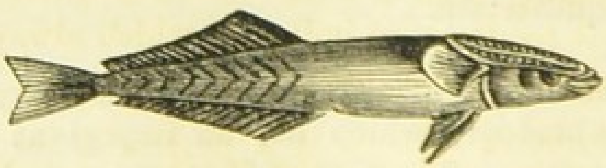


Fig 167.

nean and some other seas, presents a remarkable example of this class. The organ in question consists of a flat oblong disc composed of cartilagi-

nous movable plates, directed obliquely backwards, established over the head. The surface of this disc is represented in fig. 168. This species has been long celebrated on the shores of the Mediterranean, and its history is overlaid with fable. Thus it is pretended that it feeds by a species of suction exercised by the disc just described ; and the mariners of the coasts ascribe to it the power of suddenly stopping a vessel in its most rapid course. It appears, on more authentic grounds, that this sucking instrument is used for the seizure of its prey, and fishermen in the seas on the coast of Caffraria use it to catch other fish. For this purpose, after having tied a line to its tail, they launch it into the water, and when it attaches itself to its prey they draw it out.

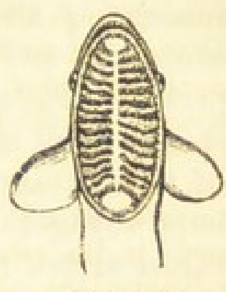


Fig. 168.

219. **Mode of Propagation.**—Fishes are propagated by means of eggs, the number of which produced at a single laying is often immense, amounting sometimes to several hundred thousand. In general the eggs are enveloped in a mucilaginous covering, and are only fecundated after being laid. Some species, however, are viviparous ; a word by which naturalists express a mode of generation in which the young has been already extricated from the egg at the moment of birth : but whatever be the manner in which the young of fishes come into life, they are invariably abandoned from the moment of their birth, and a very large proportion of them perish immediately afterwards.

It is to the simultaneous development of an enormous number of eggs deposited in one place, and to the instinct which impels the animals thus produced to keep together, that is to be attributed the assemblages of the immense legions of certain sorts of fish to which the fishermen have given the name of banks or shoals.

Such assemblages, however, cannot properly be called societies. Between the individuals which compose them there is no interchange of services ; the same physical wants probably keep them in the same locality, or impel them to the same change of place ; and if the whole assemblage be observed to follow some among their number as their guide, it is merely an effect of that tendency to imitation which always attends the first glimmerings of intelligence.

220. **Migrations.**—These animals, thus assembled in troops, often make long voyages ; sometimes to gain the deep, sometimes to ascend the embouchures of rivers, or generally to change their

quarters. Certain species, however, lead a sedentary life, remaining always in their original locality. Others, on the contrary, are always wandering, and a great number make periodic voyages of considerable length. In the spawning season they usually approach the coasts, or enter the mouths of rivers; and for this purpose sometimes make an extremely long voyage. At certain seasons, vast troops of these migratory fishes arrive regularly in the same waters; and it is generally believed that certain species migrate periodically from the north towards the south, and return from the south towards the north, following always a determinate route. Some naturalists, however, doubt this, and consider it more probable that the periodical change of place is limited from deep to shallow water, and *vice versâ*.

221. **The Herring.**—Among these migrating fishes, the species which is by far the most important in its relation to the industry of the fisheries is the herring. This fish inhabits the northern seas, and visits annually, in countless shoals, the coasts of the Old and New Continents as far south as the forty-fifth degree of latitude. Some naturalists think that these myriads retire periodically into those depths of the Polar Seas which are below the stratum of constant temperature, and therefore defended from the rigour of the surface. Issuing from this common rendezvous, they depart at the appointed season in a prodigious column, which soon, however, subdivides, sending off large divisions and numerous detachments to all the continental coasts, and more especially to all the straits and channels within the limit of latitude above mentioned.

It appears to be ascertained that the spawning regions of the herrings are near the coasts frequented by the fish; and it is supposed that the young, immediately on coming to life, withdraw into deeper waters, and direct their course to the north, where they find in much greater abundance the animalcules and small crustacea which constitute their proper food.

In spring, new wants bring them back to the shores, where they seek more shallow and tepid waters. At that season they appear in countless numbers, descending southwards.

222. **Periodical Voyages.**—In the months of April and May they begin to make their appearance around the Shetland Isles;

and towards the end of July they arrive in incalculable numbers, forming vast shoals, which extend over the surface of the sea for several leagues continuously in length and breadth. The vast multitude of these creatures may be imagined, when it is stated that such extensive shoals often have a thickness of several hundred feet.

According to Pennant, the grand winter rendezvous of the herring is within the Arctic circle ; there they continue for many months, in order to recruit themselves after the fatigues of spawning ; the seas within that limit swarming with insect food in a far greater degree than those of our warmer latitudes. This mighty army begins to put itself in motion in spring, and appears off the Shetland Isles in April and May. These, however, are only the forerunners of the grand shoal, which comes in June ; and their appearance is marked by certain signs, such as the numbers of birds, like gannets and others, which follow to prey on them ; but when the main body approaches, its breadth and depth is such as to alter the appearance of the very ocean. It is divided into distinct columns of five or six miles in length and three or four in breadth, and they drive the water before them with a kind of rippling. Sometimes they sink for the space of ten or fifteen minutes, and then rise again, and in fine weather reflect a variety of splendid colours, so that the surface of the sea resembles a field of precious gems.

The first check this army meets in its march southwards is from the Shetland Isles, which divide it into two parts : one wing takes to the eastern, the other to the western shores of Great Britain, and every bay and creek is filled with their numbers ; the former proceed towards Yarmouth, the great and ancient mart of herrings. They then pass through the British Channel, and after that in a manner disappear. Those which proceed towards the west, after passing the Hebrides, where the great fishery station is established, proceed to the north of Ireland, where they meet with a second interruption, and are obliged to make a second division ; the one takes to the western side, and is scarcely perceived, being soon lost in the immensity of the Atlantic ; but the other, that passes into the Irish Sea, rejoices and feeds the inhabitants of most of the coasts that border on it. These brigades, as we may call them, which are thus separated from the greater columns, are often capricious in their motions, and do not show an invariable attachment to their haunts.

This instinct of migration was given to the herrings that they might deposit their spawn in warmer seas, that would mature and vivify it more assuredly than those of the frozen zone. It is not from deficiency in food that they set themselves in motion; for they come to us full of fat, and on their return are almost universally observed to be lean and miserable. What their food is near the Pole we are not yet informed; but in our seas they feed much on the *oniscus marinus*, a crustaceous insect, and sometimes on their own fry.

They are full of roe in the end of June, and continue in perfection till the beginning of winter, when they deposit their spawn. The young herrings begin to approach the shores in July and August, and they are then from half an inch to two inches long. Though we have no certain authority for it, yet, as very few young herrings are found in our seas during winter, it seems most certain that they must return to their parental haunts beneath the ice. Some of the old herrings continue on our coast the whole year.

223. **Herring Fishery.**—Towards the middle of the seventeenth century, the Dutch employed in the herring fishery not fewer than two thousand vessels, and the industry gave employment to nearly a million of persons. Although the importance of this branch of industry is not so great as it has been, it still gives employment to a large proportion of the coast population of the United Kingdom and the northern parts of Europe.

The operation of the herring fishing is conducted usually with nets from five to six hundred fathoms in length, the lower edge of which is sunk by weights, and the upper edge floated by means of empty barrels. The meshes of the net are just large enough to allow a herring of ordinary size to thrust through them the head and gills, but not to let the pectoral fins pass. The fish, endeavouring to extricate itself, only becomes more entangled; the position of its gills directed backwards preventing it from withdrawing, and the magnitude of its abdomen and projecting pectoral fins preventing it from advancing. It remains therefore a prisoner, until the nets are taken up. The number of fish taken in this way is sometimes so great, that the net is filled with them, and occasionally breaks under their weight.

When the place of the fishery is very distant from the port,

the fish is salted on board, thus affording employment to the fishermen during their voyage.

224. **Dulness of the Senses.**—The tactile and other senses of fishes are extremely limited, and this class of animals seems to pass its life exclusively in seeking subsistence and flying from its enemies. It exhibits no remarkable instincts; its brain is but slightly developed, and its organs of sense very imperfect.

225. **Electric Fishes.**—Among the offensive and defensive organs of fishes, those by which certain species are enabled to develop voltaic electricity, and to inflict an electric shock on their enemies or their prey, merit especial notice. Several species are endowed with this power, and it is very remarkable that the electric organ differs altogether in its structure in one compared with another.

226. **Gymnotus Electricus.**—One of the species which possess this curious physical power is the Gymnotus electricus, or electric eel, fig. 169. This species, which inhabits Southern America, closely resembles common eels, wanting, however, the fins at the end of the tail, and no scales being visible upon its skin, which is covered with a glutinous matter. Its length is from six to seven feet, and it is commonly met with in the streams and ponds which are found in various places in the immense plains which overspread the valleys of the Cordilleras, the banks of the Oronoco, &c. The electric shocks which the animal is enabled to give at will have an intensity sufficient to paralyse not only men but horses. It uses this organ accordingly, not only to defend itself from the attacks of its enemies, but to kill at a distance the fishes on which it feeds, the water being a sufficient conductor of electricity to transmit the shock. Its first discharges are generally weak; but when the animal is irritated and roused, they become stronger, and at length acquire a terrible intensity. When the animal has communicated a certain number of these shocks, it becomes exhausted, and is forced to desist, and it is not until after the lapse of a certain interval that it is enabled to recommence. It would appear as though the electric organ, like the scientific machine, when once completely discharged, requires a continued action of the exciting power, which in this case is a vital function of the animal, to recharge it.

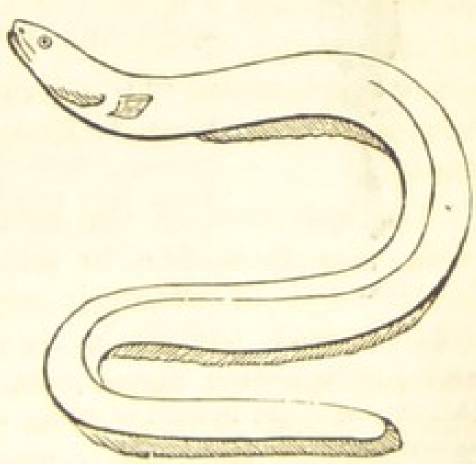


Fig. 169.
THE ELECTRIC EEL.

227. **Manner of capturing them.**—The natives of the countries which the animal inhabits avail themselves of this temporary suspension of its offensive power to capture it. Troops of wild horses are driven into the reservoir in which the creature is known to prevail; immediately the horses are fiercely attacked, receiving a rapid succession of intense electric shocks, by which they are more or less stunned and paralysed, and not unfrequently killed; but the assault has the effect of exhausting the electric eels, and rendering them comparatively inoffensive, so that they are easily captured, either by the net or harpoon.

228. **Electric Organs.**—The apparatus by which the gymnotus produces these electric shocks is extended along the entire length of the back to the tail, and consists of four longitudinal masses composed of a great number of membranous folds, connected by an infinite number of smaller membranes placed transversely to them. The small prismatic cells formed by the combination of these membranes are filled with gelatinous matter, and the whole apparatus is supplied with large nerves.

229. **The Torpedo,** fig. 170, is a flat cartilaginous fish which resembles the common ray. Its body is smooth, and has the form of a nearly circular disc, the anterior border of which is formed by two prolongations of the muscle, which are connected on each side with the pectoral fins, and which leave between these organs an oval space in which the electric apparatus is deposited.

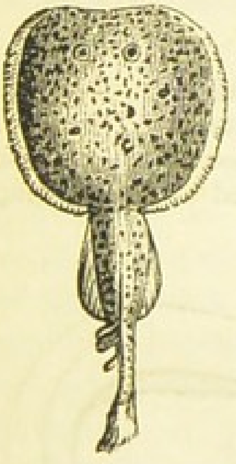


Fig. 170.
THE COMMON TORPEDO.

This apparatus, which is shown in fig. 171, is composed of a multitude of membranous tubes lying closely together, and sub-divided by horizontal partitions into small cells, like those of honeycomb, filled with mucous matter, and traversed by the ramifications of several large trunks of the pneumogastric nerves.

In the figure, A is the brain, B the spinal cord, C the eye and optic nerve, D the electric organs, E the pneumogastric nerves ramifying through this organ, F the branch of these constituting the lateral nerve, and G the spinal nerve.

These organs develop electricity, which is identified in all its physical properties with that of the voltaic apparatus. The torpedo, though less powerful than the gymnotus, is capable, nevertheless, of rendering insensible the arms of those who touch it.

It has been lately ascertained that the electric functions of these organs have a close connection with the posterior lobe of the brain, since by destroying this lobe, or dividing the nerves which proceed from it, the animal is deprived of the electric power.

There are several species of the torpedo which inhabit the seas which

wash the coast of Europe. They have been frequently found near the shores of Vendée and Provence in France.

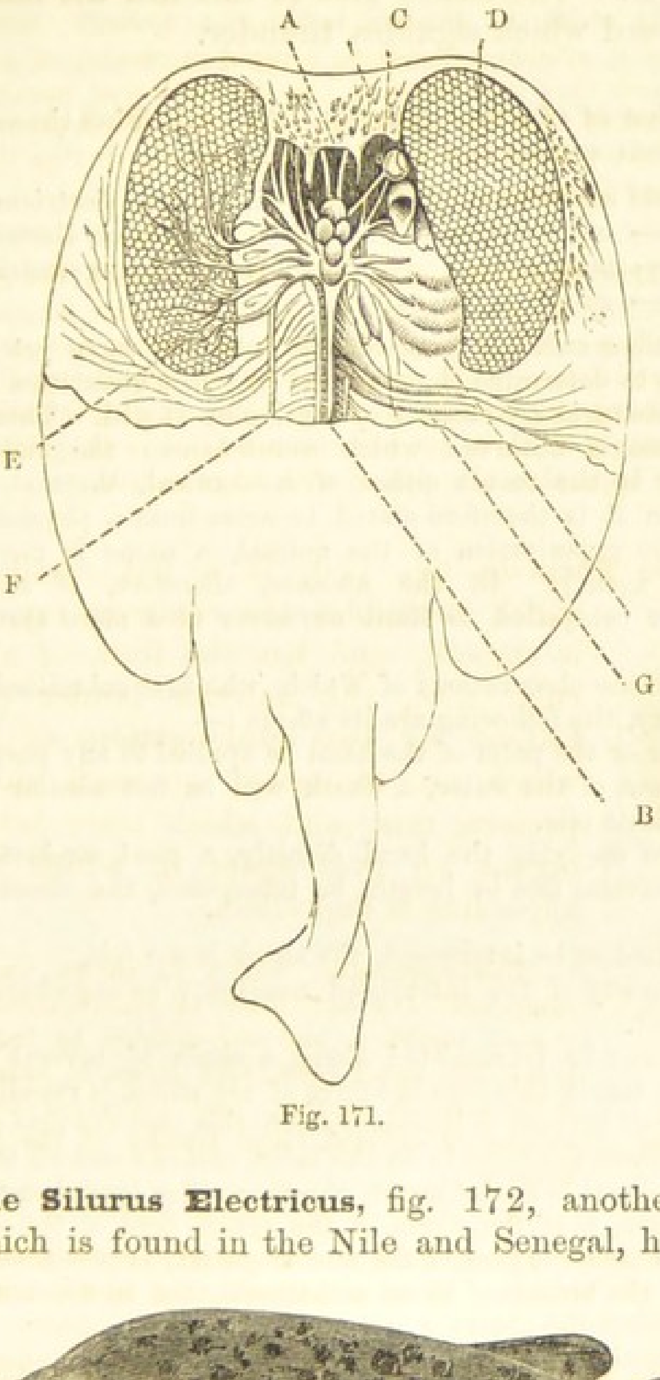


Fig. 171.

230. **The Silurus Electricus**, fig. 172, another of these species, which is found in the Nile and Senegal, has a length

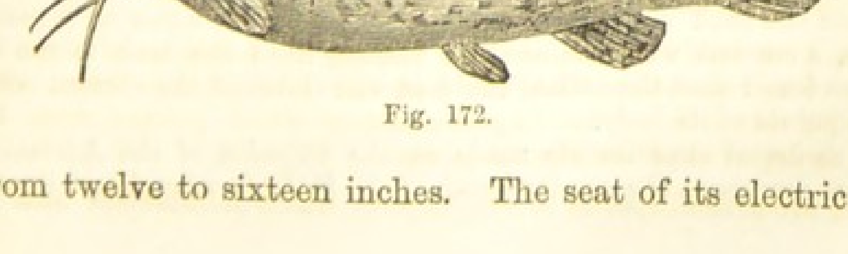


Fig. 172.

of from twelve to sixteen inches. The seat of its electric power

seems to be a particular tissue situate between the skin and the muscles of the sides, having the appearance of a foliated cellular tissue. The Arabs give to this fish the name Raasch, an Arabic word which signifies thunder.

231. **Species of electric fishes.**—Of electric fishes the seven following genera have been enumerated :—

1. Torpedo narke risso.
2. ——— unimaculata.
3. ——— marmorata.
4. ——— galvanii.
5. Silurus electricus.
6. Tetraodon electricus.
7. Gymnotus electricus.

No observations sufficiently exact and extensive have yet supplied the data necessary to determine the source of the vast quantities of electricity which these creatures are capable of developing at will. There is nothing in the phenomena observed which countenances the supposition that the electricity is the result either of mechanical, thermal, or chemical causes. When it is therefore stated to arise from a physiological action peculiar to the organisation of the animal, a name is merely given to an unknown agency. In the absence, therefore, of any reasonable theory, we are compelled to limit ourselves to a mere statement of the phenomena.

According to the observations of Walsh, who first submitted this animal to exact inquiry, the following are its effects :—

If the finger or the palm of the hand be applied to any part of the body of the animal out of the water, a shock will be felt similar to that produced by a voltaic pile.

If, instead of applying the hand directly, a good conductor, such as a rod of metal several feet in length, be interposed, the shock will still be felt.

If non-conductors be interposed, the shock is not felt.

If the continuity of the interposed conductor be anywhere broken, the shock is not felt.

The shock may be transmitted along a chain of several persons with joined hands ; but in this case the force of the shock is rapidly diminished as the number of persons is increased. In this case the first person of the chain should touch the torpedo on the belly, and the last on the back.

When the animal is in the water, the shocks are less intense than in the air.

It is evident that the development of electricity is produced by a voluntary action of the animal. It often happens that in touching it no shock is felt. But when the observer irritates the animal, shocks of increasing intensity are produced in very rapid succession. Walsh counted as many as fifty electrical discharges produced in this way in a minute.

In a series of observations and experiments made on the torpedos of Chioggia, near Venice, by MM. Becquerel and Breschet, it was ascertained that when the back and belly were connected by the wires of a sensitive reoscope, a current was indicated as passing from the back to the belly. They also found that the animal could at will transmit the current between any two points of its body.

In a series of experiments made on the torpedos of the Adriatic, M. Matteucci confirmed the results obtained by MM. Becquerel and Breschet,

and also succeeded in obtaining the spark from the current passing between the back and belly.

232. **Fossil Fishes** are more numerous than all the other vertebrated animals found in the fossil state taken together. Thus while only 400 fossil species of mammifers, 66 of birds, and 276 of reptiles have been discovered, not less than 1000 species of fossil fishes have been described. These are distributed in all the strata, from the first appearance of animal life in the lowest group to that which immediately preceded the actual epoch. As might be expected, however, the cartilaginous fishes are much more rare than the osseous. Like those of reptiles, the skeletons of osseous fishes are often found complete, the bones having retained their proper arrangement and juxtaposition, and the body being sometimes still covered with its scales. Separate bones, and especially heads, are frequently seen, but the parts which offer most resistance to destructive agencies are the teeth and small internal bones of the head, all of which are found in strata from which all other bones have disappeared.

In fig. 173 is shown a group of fishes, Lebias Cephalotes

Fig. 173.

LEBIAS CEPHALOTES. (FOSSIL.)

found at Aix, in Provence, in the tertiary strata. This was a fresh-water species, several genera of which still exist.

In fig. 174 is shown a specimen of the family plataxidæ (squamipennis). In this family the base and even the spinous part of the dorsal fins are covered with scales. The body is

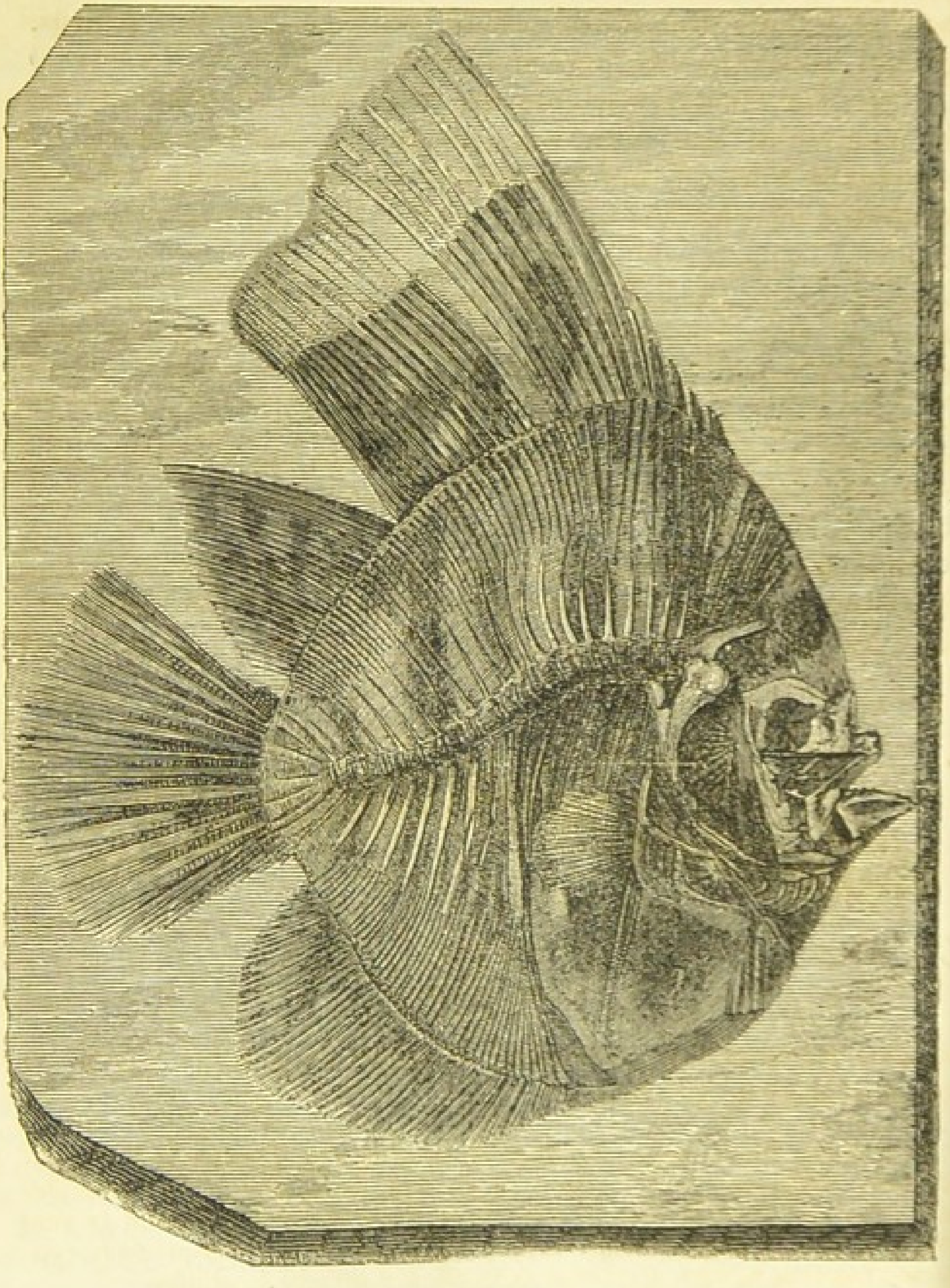


Fig. 174.
PLATÆ ALTISSIMUS. (FOSSIL).

compressed. Of ten genera which have been found in the fossil state, three are extinct.

INVERTEBRATE ANIMALS.

233. The presence or absence of a vertebral column and internal skeleton is the most conspicuous mark of distinction among animals, and all naturalists agree in adopting it as the basis of the division of the animal kingdom into two principal groups, called the *vertebrate* and the *invertebrate.*

234. The invertebrate animals, while they are generally less in magnitude, are infinitely greater in number than the vertebrate, some of their numerous genera consisting of some thousands of species.

They may be distributed, as regards their general appearance, into three principal groups; the *first* including the animals of Annulose structure; the *second*, Mollusca—a Latin word, signifying *soft*—which includes those animals whose bodies are soft, and not annulose or articulated, some of which are enveloped in shells, such as snails and oysters, while others are destitute of that covering; and the *third*, Zoophytes, being the lowest grade of the animal kingdom, which takes its name from two Greek words —ζωον (zōōn), an animal, and φυτον (phuton), a vegetable.

235. **Animals of Annulose Structure** have a body round in its transverse section, the diameter being generally much less than its length, and the length being composed of a series of

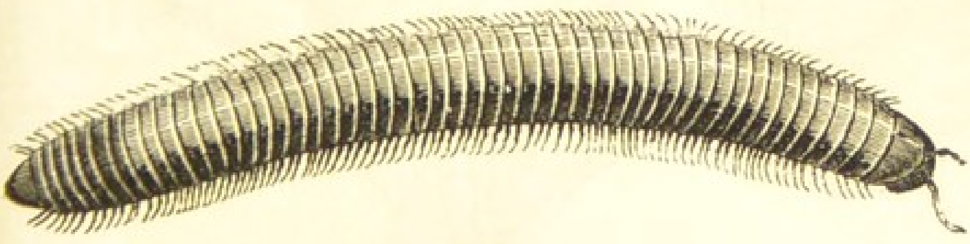


Fig. 175.
THE IULUS.

annular segments, so connected together as to allow more or less flexibility to the body.

With some, this annular structure consists merely of transverse folds of the skin which surround the body in grooves, as is seen in the examples of leeches and worms; but in most cases the body of the animal is surrounded with a sort of solid sheath, composed of a series of rings connected together in such a manner as to allow a certain flexibility.

This jointed sheathing supplies in this division of the animal kingdom the place of the internal skeleton of the vertebrates. It determines the general form, protects the soft parts which it encloses, supplies points of reaction to the muscles, and gives these organs levers adapted to confer a certain degree of promptitude and precision on the motions. Some naturalists have therefore called it the *external skeleton*, to which,

however, others object, inasmuch as this sheathing is the analogue not of the skeleton, but of the tegumentary covering of the vertebrates.

In general, the annular segments composing the body bear a close similitude to each other, differing in nothing except in their magnitude, and in many cases corresponding even in that, as in the example of the Iulus (fig. 175), each segment being considered as consisting of a dorsal and ventral semicircle. To each of these semicircles are in general articulated

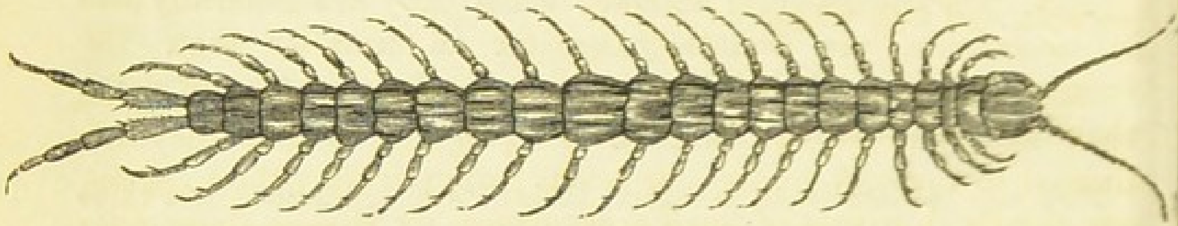


Fig. 176.
SCOLOPENDRA.

a pair of members. In those of the most simple structure, all the segments are provided with these members, equally developed; and their

Fig. 177.
THE COMMON SPIDER.

number, consequently, in that case, is often very great; but, most commonly,

while the members attached to particular segments are fully developed, those attached to the others are either rudimentary or altogether absent. In most cases the members thus attached to the ventral semicircle are more developed, and assume forms so much the more varied as the animal i higher in the scale of organisation, forming feet, antennæ, paddles, organs of mastication, &c. Sometimes the members attached to the dorsal semicircle are endowed, like those of the ventral, with the functions of feet, but more generally these are only attached to two, and sometimes only to one segment, and form wings.

236. The number of feet is very various; while, in some, they are counted by hundreds of pairs, in others they are limited to three, four, five, or seven pairs; while others, again, are totally destitute of such appendages, or possess them only in a rudimentary form, as in the example of the common earthworm.

237. Articulated animals properly so called are distributed in four classes:

1°. Insects, characterised by a body consisting of a head, a thorax, and an abdomen distinct one from another, and, in most cases, wings.

2°. Myriapoda, characterised by the absence of any distinction between the thorax and abdomen, the absence of wings, and twenty-four or more pairs of feet (figs. 175 and 176).

3°. Arachnida, characterised by the absence of any distinct separation between the head and thorax, the absence of antennæ, and by four pairs of feet. The common spider (fig. 177) presents an example of this class.

4°. Crustacea, having five or seven pairs of feet, and some peculiarities in their vascular and respiratory functions, which will be noticed hereafter.

INSECTS.

238. The general characters by which the structure of insects is distinguished, are shown in fig. 178.

Although the tegumentary sheathing of insects has generally some flexibility, its consistency is horny, without however having the chemical character of that substance. The annular segments comprising the body are, as already explained, divided into three separate sets; a single segment comprising the head, in which the eyes, antennæ, and appendages of the mouth are inserted.

Three segments,—the prothorax, the mesothorax, and the metathorax,—compose the thorax, which is the centre part of the body. To the ventral division of each of these segments a pair of legs is articulated. In most species, the two posterior segments of the thorax carry wings, but the anterior segment, or prothorax, is never furnished with these appendages. No insect, therefore, has more than two pairs of wings. In some few

genera, the number is reduced to a single pair, whence they are denomi-

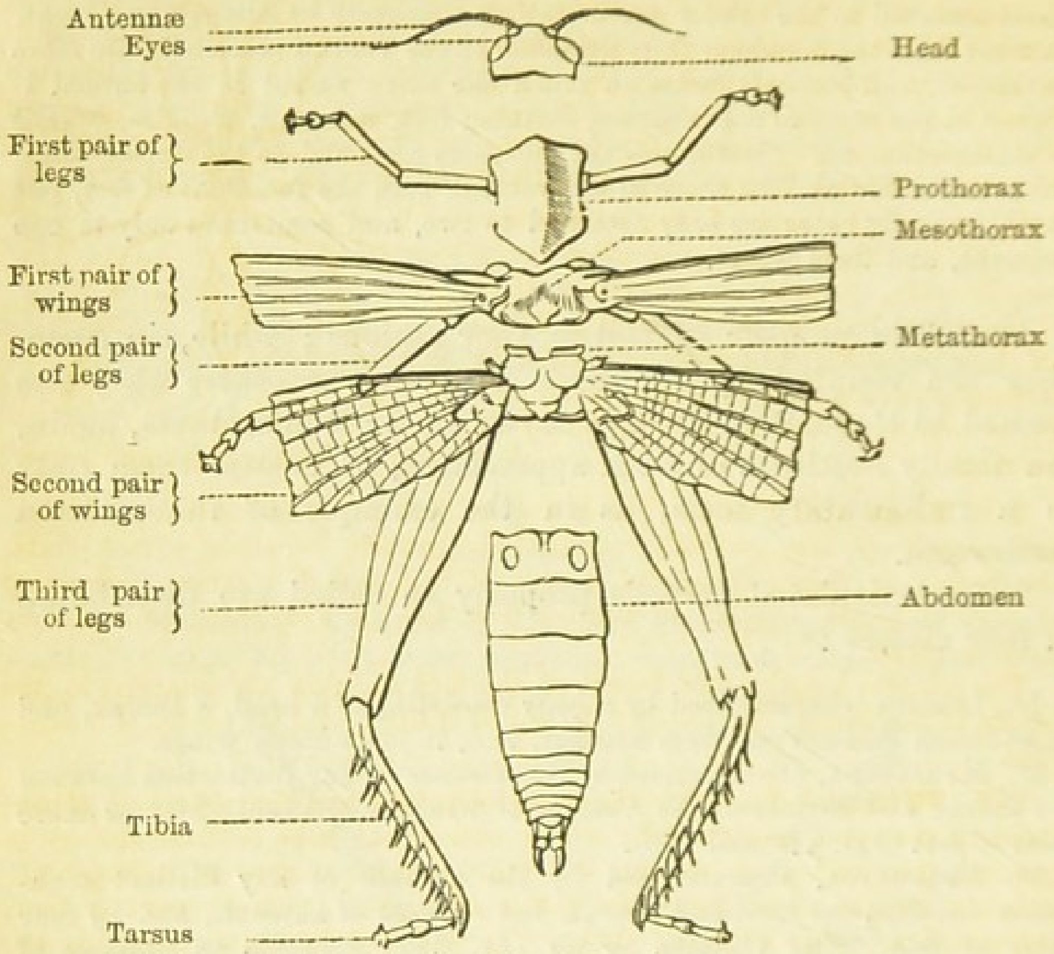


Fig. 178.
STRUCTURE OF THE TEGUMENTARY SKELETON OF THE GRASSHOPPER.

nated *diptera;* and in some, these appendages are altogether wanting, the family being then distinguished as *aptera.*

239. **Antennæ.**—These appendages vary extremely in form and mag-

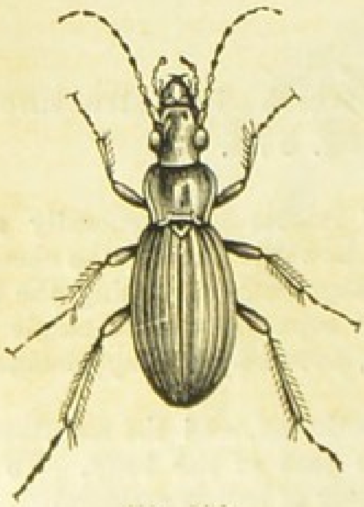


Fig. 179.
CARRABUS, OR LAND BEETLE.

Fig. 180.
THE MARINE NECROPHORUS.

nitude. They generally have the form of slender and flexible horns

(fig. 179), issuing from either side of the head. Sometimes they are feathered, as in fig. 189 ; sometimes they have the form of maces or clubs having a knob at their extremities (fig. 180.) Sometimes they have the form of saws, and sometimes they terminate in curls, like the artificial forms given to ladies' hair, as in the case of the ichneumon (fig. 181). Their length is often very considerable, sometimes exceeding that of the whole body of the insect (fig. 190). Of their physiological functions nothing is certainly known, but they are presumed to be organs of touch, and probably of hearing.

Fig. 181.
THE ICHNEUMON.

240. **Legs and Feet.**—These are subject to great varieties of form and magnitude, but generally consist of the haunch, composed of two joints, the femur or thigh, tibia, and a sort of foot called a tarsus, consisting of several joints, varying in number from two to five, and terminated by nails or claws.

The relative lengths and forms of the legs and feet are adapted to the habits of the insect, the medium in which it lives, and its modes of locomotion.

241. **Wings.**—These are the most important and characteristic appendages of the class, and those by which naturalists have resolved insects in general into tribes or orders. Of the infinite variety of invertebrate animals, insects alone enjoy the power of flight. "Every part of their organisation," says Professor Owen, "is modified in subserviency to the full fruition of these instruments of flight. In no other part of the animal kingdom is the organisation for flight so perfect, so apt to that end as in the class of insects. The swallow cannot match the dragon-fly in flight. This insect has been seen to outstrip and elude its swift pursuer of the feathered class ; nay, it can do more in the air than any bird. It can fly backwards and sidelong, to the right or to the left, as well as forwards, and can alter its course on the instant without turning."

The wings usually consist of a double membrane, supported by a strong intermediate framework, just as the sails of a windmill are spread upon its arms, or those of a ship upon its yards. When they are imperfectly developed, they are soft and flexible, but they soon harden and acquire stiffness and elasticity. No insect has more than two pairs, which, as has been already stated, are attached to the middle and posterior segments of the thorax. Sometimes, however, one or the other of these pairs are either wholly wanting, or exist in a rudimentary state. Sometimes the foremost pair are thick, hard, and opaque, and in that case serve merely as covers, sheaths, or cases, for the posterior pair, which are then the efficient

Fig. 182.
THE PLUMED MOTH.

instruments of flight — the foremost pair being called wing-cases or elytra.

The wings which are really efficient for flight are either thin and transparent, or covered and rendered opaque by a fine coloured dust, the particles of which, when submitted to the microscope, prove to be scales of most curious and beautiful form and structure.

The wings sometimes consist of a number of independent barbed membranes placed in juxtaposition, like the feathers which form a lady's fan. An example of this structure is presented in the case of the plumed moth (fig. 182).

242. The nomenclature by which the classification of insects is expressed, consists of a system of terms having reference to the form and characters of the wings. The Greek word πτερὰ (*ptera*), signifying wings, is adopted as its terminal syllables, preceded by some other Greek derivative expressive of the character of the wings in each particular order.

The following table shows the twelve orders adopted by Kirby and some other naturalists. These, however, are subject to some modification; naturalists not being yet fully agreed upon the adoption of a common classification.

243. **The Twelve Orders of Insects.**

	Name of the Order.	Signification.	Examples.	
I.	Coleoptera.	Sheath-winged.	Beetles.	Figs. 179, 194.
II.	Strepsiptera.	Twisted-winged.	Stylops, Xenos.	
III.	Dermaptera.	Skin-winged.	Earwigs.	
IV.	Orthoptera.	Straight-winged.	Crickets, Locusts, Grasshoppers.	
V.	Hemiptera.	Half-winged.	Bugs, Water-scorpions, Plant-lice.	
VI.	Trichoptera.	Hairy-winged.	Caddice-flies and Water-moths.	
VII.	Lepidoptera.	Scale-winged.	Butterflies and Moths.	Figs. 186, 189.
VIII.	Neuroptera.	Nerve-winged.	Dragon-flies.	Fig. 183.

THE TWELVE ORDERS OF INSECTS (CONTINUED).

	Name of the Order.	Signification.	Examples.	
IX.	Hymenoptera.	Membrane-winged.	Bees, Ants.	
X.	Diptera.	Two-winged.	Flies, Gnats.	
XI.	Aphaniptera.	Hidden-winged.	Fleas.	
XII.	Aptera.	Wingless.	Mites, Lice.	Fig. 199.

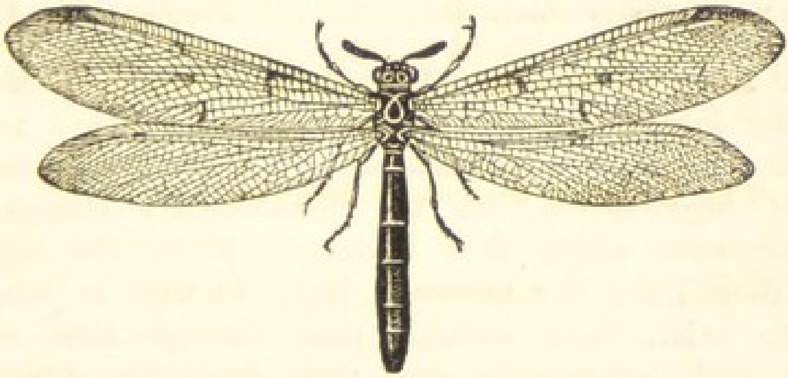


Fig. 183.

THE ANT LION.

244. **Abdomen.**—This is generally composed of annular segments, which sometimes amount to nine in number. They are jointed together so as to be distinguishable one from another in some cases, but are often so united that two or more of them form a single segment. These segments in the full-grown insect never carry either legs or wings, but their posterior extremity generally carries appendages consisting either of simple hairs or bristles, which sometimes have considerable length, as, for example, in the day-fly (fig. 190).

In some insects this part of the body is the seat of the offensive weapon called the sting, which is a dart formed of a double point lodged in a horny sheath, along which there is a groove, through which the poison, secreted in an adjacent gland, is ejected. In the state of repose, this weapon remains within the body of the animal, but when provoked, it is enabled to dart it out to plunge it in the skin of the offender, and to deposit there its poison. It is often impossible to withdraw it, in which case it remains implanted in the wound, and the animal from which it is torn dies. The male insect is almost always destitute of this weapon.

In fig. 183*a*, is represented the sting of a bee with its appendages; and in fig. 183*b* the same, highly magnified: *a a* are the muscles which propel it;

b b the sides of its sheath; *c* the two parts of the barbed dart in juxtaposition; *d* the gland in which the poison is secreted.

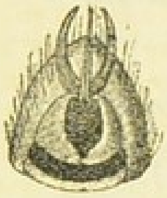


Fig. 183*a*.
POSTERIOR EXTREMITY OF THE ABDOMEN OF A BEE, WITH THE STING PROTRUDED.

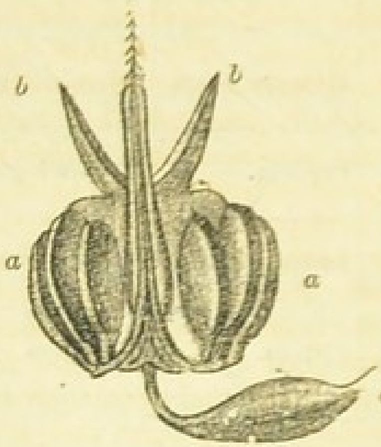


Fig. 183*b*.
STING OF A BEE, WITH ITS APPENDAGES MAGNIFIED.

245. **Metamorphoses.**—The most singular circumstances attending insects, by which they are distinguished most conspicuously from all other classes, above or below them, in the scale of organisation, are the extraordinary changes called metamorphoses which they undergo. From the moment at which they leave the maternal body to that in which they cease to exist, these animals pass through four successive stages; and, strange to say, their functions differ in the different successive stages more than do those of the most different species of animals. Not only, however, do these extraordinary changes of function take place, but they are accompanied by changes still more extraordinary of form and habits.

"If," says Kirby, "any one were to announce that he had discovered an animal which for the first five years of its life had the form of a serpent—which then, penetrating into the earth, and weaving a shroud of pure silk of the finest texture, contracted itself within this covering so as to resemble more than anything else an Egyptian mummy, and which, in fine, after remaining thus without food or motion for three years longer, should then burst its silken cerements, struggle through its covering, and start into day a winged bird, what would be the sensation excited by so extraordinary an announcement?" Yet this description, overstrained and exaggerated as it may appear, includes nothing more extraordinary than what is displayed in the life of many an insect which

in its mature form flutters and buzzes around us on a summer's day.

Insects being oviparous, their first state on leaving the maternal body is that of an egg. The mother, by a Heaven-bestowed instinct, foresees the habits, appetites, and wants of the young, which is destined to issue from her egg only after she has herself ceased to live. She foresees this with unerring precision and certainty, although these habits, appetites, and wants, are utterly foreign to, and at variance with her own. When she is about to deposit her eggs, she therefore seeks the objects upon which her future young, in their first stage of existence, are destined to live, and there she deposits the eggs, taking the most tender care for their protection from the inclemency of the elements and the attacks of their enemies. If they are destined to feed upon the foliage of a particular tree or plant, she seeks for these, and upon their leaves she deposits the eggs, often so as to be sheltered from light and other physical agencies which might injure them. If they are destined to live in water, she seeks a suitable pool or stream, and deposits them at its margin, upon its surface, or upon the aquatic plants which grow in it. In due time, these eggs are hatched by the natural effects of temperature, the parent in most cases dying in the meanwhile, and the young issue from them in the first stage of their existence, to which Linnæus applied the Latin name *larva*, which signifies a mask, inasmuch as this first form differs as much from that of the insect in a state of maturity, as the grotesque disguise of a person at a masquerade differs from his true appearance.

This larva state differs extremely in different species of insects ; in some being that of a grub or maggot, in others, that of a caterpillar, and in others, that of the most voracious inhabitants of water.

After having continued a due time, which is more or less in different species, in this state of larva, the creature prepares itself to pass into the third stage, which is called that of *pupa*, *nymph*, or *chrysalis*. In this state it continues, either enveloped in a sort of swaddling-clothes, from whence it takes the name of pupa, which signifies a baby, or entombs itself either in the earth or in some other place of secure shelter or concealment, where it remains until, by the due discharge of certain functions, it is prepared to issue forth in its perfect state, which has received the name of *imago*, and which is as various in form and character as are the thousand species of insects which inhabit every climate.

246. **Examples.—Machaon Butterfly.**—This insect presents an example of a metamorphosis, the larva stage of which is that of the caterpillar

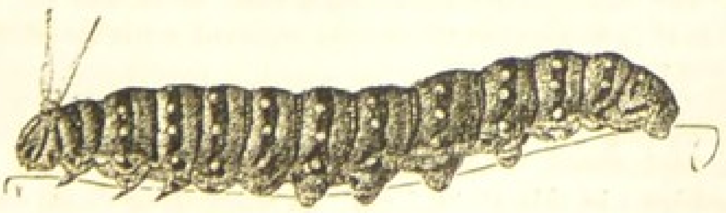


Fig. 184.

CATERPILLAR OF THE MACHAON BUTTERFLY.

(fig. 184). In this case the animal, after passing into the state of pupa or

chrysalis, suspends itself by a filament (fig. 185); and, in fine, after its perfect organisation has been developed, it breaks out of its prison, expand-

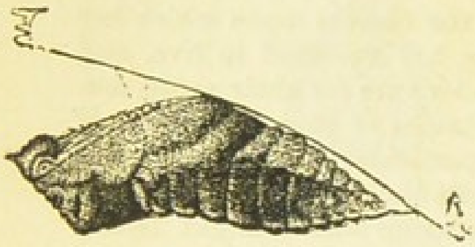


Fig. 185.
CHRYSALIS OF THE MACHAON BUTTERFLY.

Fig. 186.
MACHAON BUTTERFLY.

ing its gaudy wings, and rises in the air as the butterfly shown in fig. 186.

247. **The Silkworm.**—Of all the examples which the insect world presents of these marvellous changes, the most interesting in every point of view are those which mark the successive stages of the life of the bombyx mori, or the mulberry-tree moth, so called because the caterpillar which forms its first stage of existence feeds upon the leaves of that tree.

248. This insect is indigenous in the northern provinces of China, and was introduced into Europe in the fifth century. In the time of Justinian, the Greek missionaries returning from the East brought its eggs to Constantinople, where their culture was so speedily advanced, that it occupied the agriculturists of Sicily and Italy extensively at the epoch of the first crusades. It was not, however, until the reign of Henry IV. of France that the industry had spread into the southern provinces of that country, to the prosperity of which it now so largely contributes.

249. When the eggs of the moth, which the cultivators call the silkworm's seed (*graine de ver à soie*), are exposed to the air, they have an ashy-grey colour, and may be preserved without deterioration for a considerable time. They are hatched by exposure to a temperature of about 60^0 Fahr. The caterpillar which issues from them has the form represented in fig. 187, the length when first received from the egg being little more than the tenth of an inch.

250. The food of this caterpillar is the leaves of the mulberry-tree; the species called the white mulberry being those generally used by the cultivators.

The insect lives in this state for about thirty-four days, during which it changes its skin four times. It is calculated that the caterpillars produced by an ounce of eggs will devour, before they assume the pupa state, as much as fifteen hundredweight of mulberry-leaves. A tree forty or fifty feet high, in good average condition, will not produce, on an average, more

than seven or eight hundredweight of leaves in the season; and conse-

Fig. 187.
SILKWORM ON THE MULBERRY-LEAF.

quently the caterpillars produced by an ounce of eggs would consume the entire foliage of two such trees.

251. When passing into the pupa state, the body of the caterpillar becomes soft, and a filament of silk issues from its mouth, which it draws after it. They then roll round them a multitude of these threads of extreme fineness, and proceed to spin their cocoon, which they construct by giving themselves a continual rotatory motion, rolling round their body constantly the thread which issues from their mouth.

252. The colour of this natural silk varies, being sometimes yellow, and sometimes a brilliant white; the length of the thread spun by the insect often exceeding six hundred yards. It is calculated that the average produce of the cocoons proceeding from an ounce of eggs is from seventy to eighty pounds' weight of silk.

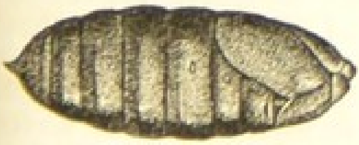


Fig. 188.
CHRYSALIS OF THE SILKWORM.

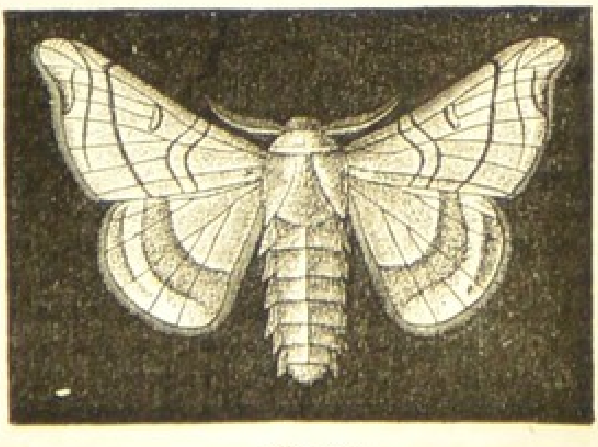


Fig. 189.
BOMBYX MORI, OR SILKWORM MOTH.

253. In general, three or four days suffice for the insect to complete its

cocoon ; and when the surrounding silk has been removed, the animal no longer presents the same appearance. It has the form represented in fig. 188, in which neither head nor members are distinguishable. On the eighteenth or twentieth day they pierce their cocoon, and issue forth from it in the form of the moth represented in fig. 189.

Immediately after arriving thus at maturity, the moth seeks its mate, and soon proceeds to deposit its eggs, the number of which generally exceeds 500 ; and, after having thus lived for a fortnight or three weeks, it dies.

254. **The Day-Fly.**—The ephemera, or day-fly (fig. 190), is one of the numerous class of insects which have aquatic larvæ, characterised by

Fig. 190.
THE EPHEMERA, OR DAY-FLY.

habits and form, contrasted in the most extraordinary manner with those which it is destined to assume in the perfect state.

This insect deposits its eggs in water, well knowing, as it would seem, that its young, when hatched, are destined to be aquatic animals, although it is itself one of the gayest animals of the air. In due time, generally towards the decline of summer, the young, breaking the shell, issues from the egg ; its length, when full grown, in this state, is about half-an-inch, and it is represented in its proper magnitude in fig. 191. It is represented magnified in its linear dimensions $6\frac{1}{2}$ times, and, therefore, in its superficial dimensions, 42 times, in fig. 192.*

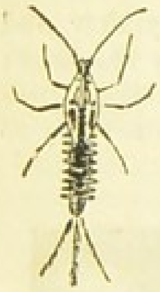


Fig. 191.

255. As the larva increases in size, the serpentine vessels attached to its sides become more apparent, and the tail assumes that rich feathered appearance which, in conjunction with the paddles projecting from its sides, constitute one of its most beautiful features.

The body of the insect when young, being very pellucid, its internal organisation may be very clearly seen with the microscope by light transmitted through it. The peristaltic motion of the intestines, the circulation of blood, and the pulsations of the dorsal vessel, which in these creatures supplies the place of a heart, can be observed with the greatest facility. As it grows, it assumes a variety of colours, losing much of its transparency, when it is a few months old; at which time, the period approaches at which it is destined to pass into the second stage of its existence. The eyes, as will be seen in the figure, are large, protuberant, and curiously reticulated ; they are of a citron colour. The body exhibits

* This figure and the succeeding ones, drawn by Dr. Goring, have been copied, with the permission of Mr. Pritchard, from the microscopic illustrations.

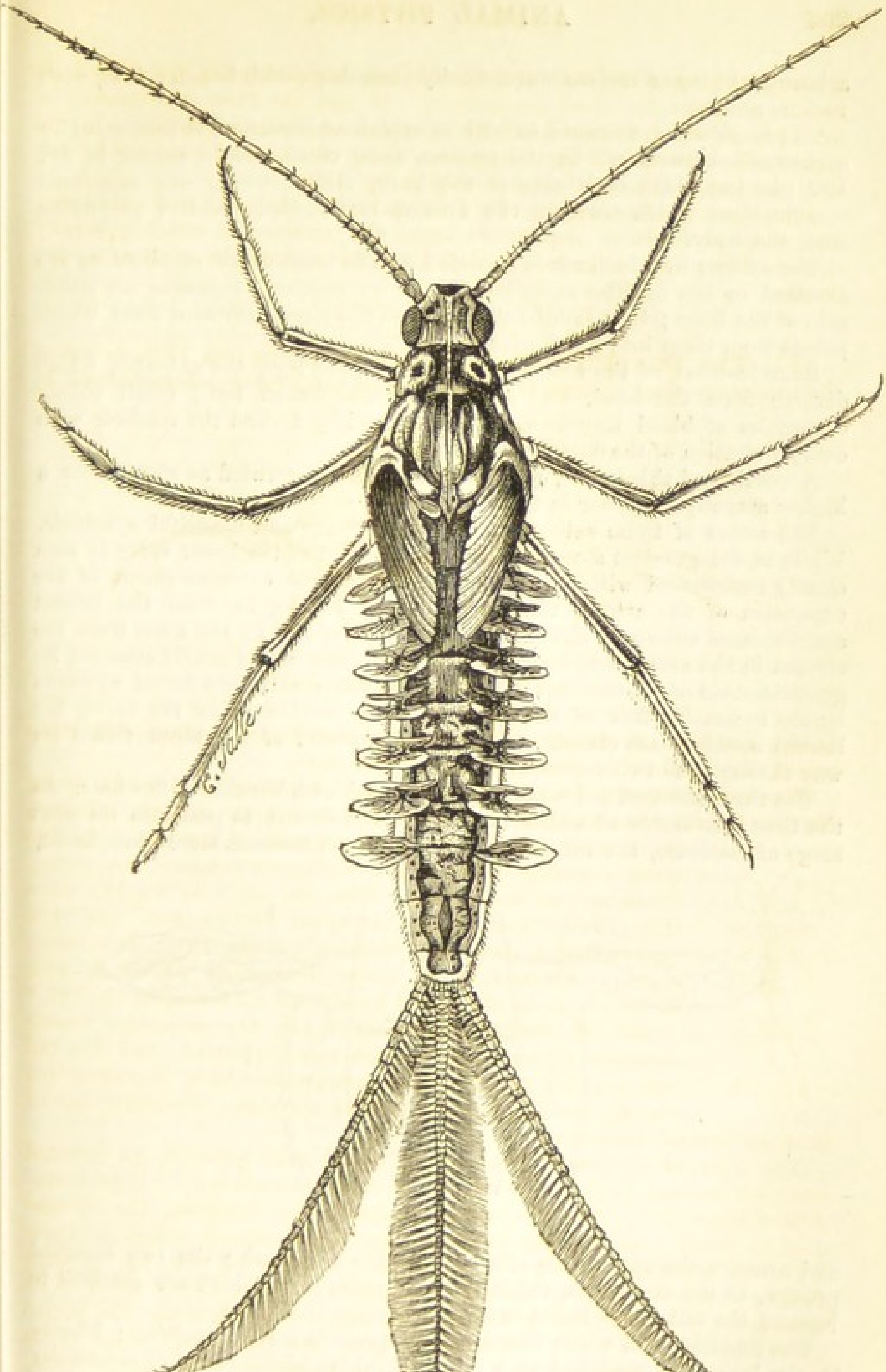


Fig 192.—MAGNIFIED VIEW OF THE LARVA OF THE DAY-FLY. DRAWN BY DR. GORING.

a beautiful play of various tints, finally assuming a rich brown colour, with various shadings.

The respiration of insects, as will be explained hereafter, is performed by organs called tracheæ. In the present case, these vessels appear in fig. 192 running along each side of the body, and throwing out numerous ramifications which traverse the several leaf-shaped paddles projecting from the body.

The orifices by which air is supplied to the tracheæ for respiration, are situated in the membraneous paddles, or swimmers, projecting on either side of the body ; they imbibe the air from the circumambient fluid which passes from them into the tracheæ.

Ramifications of the tracheæ extend along the legs, the antennæ, which diverge from the head, and along the three-forked tail ; small oblong corpuscles of blood may be seen passing rapidly around the tracheæ with every pulsation of the dorsal vessel.

A portion of this vessel, with its valves, is represented as seen under a higher magnifying power in fig. 193.

The action of these valves is a most interesting and beautiful spectacle. While in the greatest state of collapse, the point of the lower valve is seen closely compressed within the upper one. At the commencement of the expansion of the artery, the blood is seen flowing in from the lateral apertures, as shown by the arrows in the figure, and at the same time the stream in the artery commences its ascent ; when it has nearly attained its greatest state of expansion, the sides of the lower valve are forced upwards by the increasing flow of the blood from the section below the valve, the lateral openings are closed, and the main current of the blood forces its way through the two valves.

The three-pronged tail is beautifully fringed with bunches of fine hair. As the time approaches at which the insect is destined to pass into its next stage of existence, the central prong of the tail becomes more transparent,

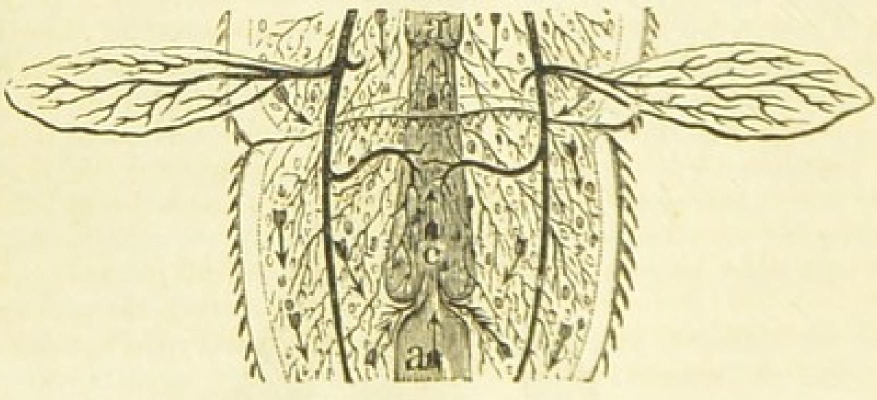


Fig. 193.

and assumes the appearance of a jointed tube or sheath ; the two external prongs, at the same time, exhibit within them parts which are destined to become the tail of the insect in the third stage of its life.

The rapidity with which this creature moves is truly surprising ; besides its six legs, it is furnished with the six double paddles attached diagonally to the serpentine vessels on each side of its body, and with its tail, all of which it employs for rowing, balancing, and guiding itself in the water, the tail playing the part of the rudder.

256. Such is the mobility of these members, that even when the creature

is in repose, all the paddles are in rapid motion ; the steering prong of the tail alone being at rest.

Independent of its faculty of locomotion by means of its legs, paddles, and tail, it possesses a power of leaping and springing in the water, by bending its body backwards, and then suddenly straightening it ; by this movement it raises itself to the surface with great celerity.

During the second stage of the life of this insect, called the state of chrysalis, it retains the faculty of swimming ; its motions are altogether subservient to its will, and it leaps with great alacrity. As the epoch, however, approaches at which it is to pass into the third and most perfect state, in which it receives the name of day-fly, some parts of it assume a metallic lustre, just as if the thin casing, in which it is wrapped like a mummy, were partly filled with mercury; this casing is so thin and translucent, that every part of the body of the perfect insect, which is soon about to emerge from it, is plainly enough visible through it.

257. When the creature has divested itself of its envelope, it remains apparently inert for a few minutes on some neighbouring plant, where it carefully cleanses its wings, and divests them of the last pellicle of the sheath in which they had been inserted ; it then assumes the beautiful form, and exercises the functions which appertain to it in the perfect state, and becomes the day-fly shown in fig. 190.

It now rises upon its wings into its new element, the air, where it joins tens of thousands of its fellows, who have almost simultaneously undergone a similar transformation. In the fine afternoons of summer and autumn, swarms of these creatures may be seen hovering in the air, all of them having emerged the same day from the state of chrysalis. Each female in these flights seeks her mate ; which having chosen, they retire together to the leaves of some neighbouring plants. Immediately after their conjugal union, their proceedings are such as would be prompted by the tenderest parental solicitude for their future offspring, which, however, they are never destined to behold. Conscious, apparently, that their young must inhabit a very different element from that in which their short existence passes, they fly off in quest of water, in which, when found, the provident mother deposits her eggs, collected in a little packet in which they can float ; the parents then abandon them to the warmth of the atmosphere, by which they are subsequently hatched, and having thus performed the last and most important duty of their life, that of increasing and multiplying their species, they drop dead, the whole period of the existence of this gay insect being limited to a few hours of a summer afternoon.

It appears, that in some localities, these flies prevail in such countless numbers that their bodies are found after death covering the ground to a considerable depth, and they are collected in cart-loads by the agriculturists, who use them for the purpose of manure.

258. **The Beetle** (fig. 194).—The larva of this insect, like the former, is also an inhabitant of the water. It is remarkable for its ferocious and savage disposition, and for the various organs supplied to it by nature for the gratification of its ravenous propensities. It may be truly affirmed that no similar creature is provided with weapons of destruction so powerful, so numerous, and so perfectly adapted to their end ; it is on this account, that the insect, in this first state of its existence, has been vulgarly called the "water-devil." Its length, when full grown, is about an inch and a half, and the strength, courage, and ferocity with which it

attacks small fish and other aquatic animals larger than itself, are truly surprising.

The representation of this creature, in its natural size, when young, and before it has reached its full growth, is given in fig. 195.

The magnified representation of it given in fig. 196, has been engraved from Dr. Goring's drawing.

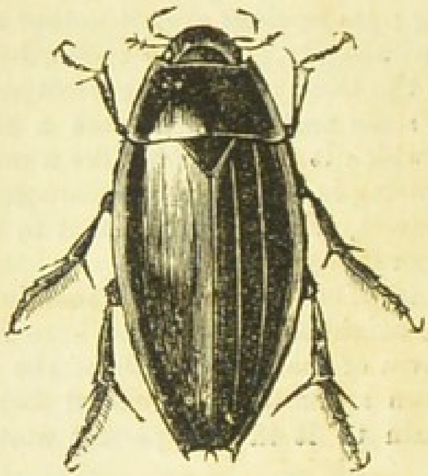


Fig. 194.

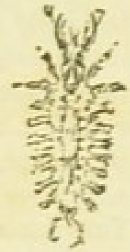


Fig. 195.

In the first months of spring, small nests containing the eggs of these insects may be seen floating among the weeds, in stagnant pools; they are formed like balls of a dusky-white colour, and silky texture; they are attached to the roots or stalks of weeds at the bottom of the water by a thin stem of the same material as the nest, but stronger and more dense. Thus placed, they remain during the winter preserved from the effects of cold, even when the surface of the water is frozen over: since, by a natural thermal law, the temperature increases in going downwards.

Early in spring, the stem or thread by which they are attached to the weeds is broken by the winds; and the nest being detached, and lighter, bulk for bulk, than the water, rises by its buoyancy to the surface, where, being exposed to the warmth of the sun as the season advances, the eggs are hatched. The larva, however, after breaking the shell, is still confined in the bag-shaped nest; it accomplishes its liberation by gnawing a hole in it, from which escaping, it dives immediately to the bottom, eagerly devouring all the small aquatic insects that fall in its way. If, however, it should happen that there is a short supply of this food, the voracity of these creatures is such, that they fall upon and devour each other.

259. When the larva is very young, measuring not above a quarter of an inch in length, it is sufficiently translucent to enable an observer to see its internal structure with the microscope, by light transmitted through it. The colour of the head is then a strong Indian yellow, with darker shadings of a bright chesnut. The eyes are a brilliant carmine; its covering of hairs is more sparse than when it arrives at maturity; its swimmers or paddles are shorter, and its head bears a greater proportion to its body.

The manner in which it deals with its prey, shows extraordinary intelligence; many of the creatures upon which it feeds, being crustaceous, are invested on the head and back with a shell armour, being unprotected on

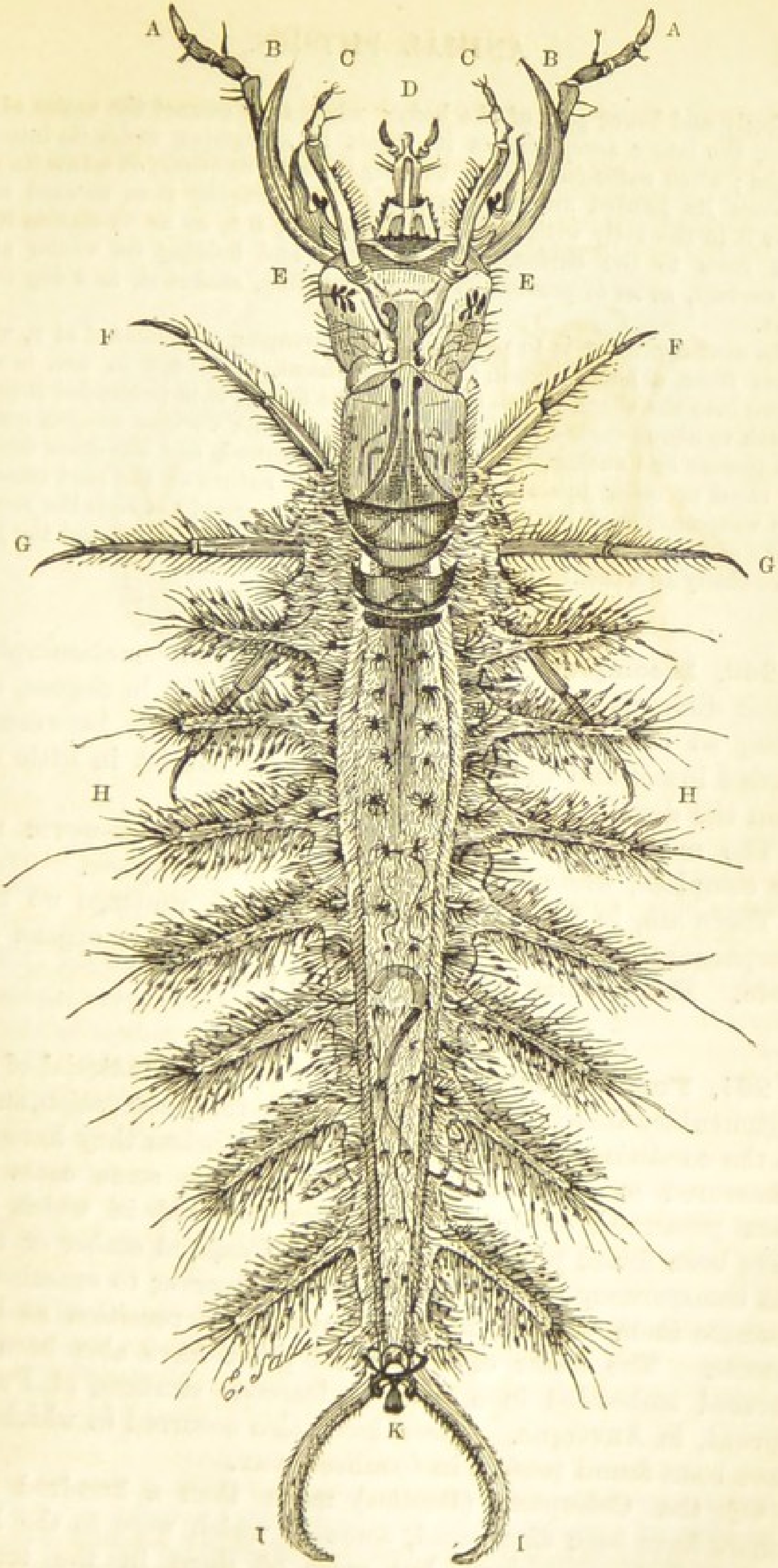


Fig. 196.—MAGNIFIED VIEW OF THE WATER-DEVIL, OR LARVA OF THE BEETLE.

the belly and lower part of the body; when they attract the notice of the larva, the latter accomplishes its object by swimming under its intended victim; when sufficiently near, turning its head upwards, it seizes its prey between its jointed antennæ, A A, fig. 196; having thus secured it, it stabs it in the belly with its sharp mandibles, B B, so as to disable it; it then rises to the surface of the water, and holding its victim above the surface, so as to prevent it from struggling, shakes it, as a dog would a rat.

Its next operation is to pierce it with a weapon, represented at D, which issues from a horny sheath; this instrument, when not in use, is withdrawn into the sheath. As shown in the figure, it is protruded from the sheath to about three-fourths of its length. This curious weapon consists of a piercer and sucker, the one giving the wound, and the other drawing the blood or other juices. When, from the nature of the part attacked, this weapon fails of its purpose, the victim is seized between the serrated hooks of a pair of forceps, C C, by which it is torn to pieces, and the juices more easily approached by the sucker, D.

260. **Incomplete Metamorphoses.** — The metamorphoses which different orders of insects undergo differ in degree, some being so complete as to efface all resemblance between the perfect insect and the larva, while others consist in little more than the development of the wings.

The metamorphoses of the butterfly and silk-worm moth are complete, while that of the day-fly is incomplete.

There are, in fine, certain insects which undergo no metamorphoses, coming into the world with all their organs complete. This peculiarity is confined to the aptera.

261. **Fossil Insects** are necessarily rare, the material of their tegumentary skeleton being unfavourable for preservation, subject to the conditions of fossilisation. Nevertheless they have been discovered in considerable numbers, and in some cases have been preserved entire. Cases have occurred in which they have been found preserved perfect in fossilised amber or resin, the transparency of which enables the observer to examine and describe them with as much certainty and precision as living insects. The forms of larvæ and pupæ have also been discovered embedded in a marly calcareous stratum, at Puy de Covent, in Auvergne. Cases have also occurred in which they have been found perfect in fossilised wax.

Of the Coleoptera (Beetles) more than a hundred fossil genera have been discovered, some of which were in the lower strata of the secondary, but most of them in the tertiary group.

In fig. 197 is shown the fossil remains of a dragon-fly, found in the Jurassic group.

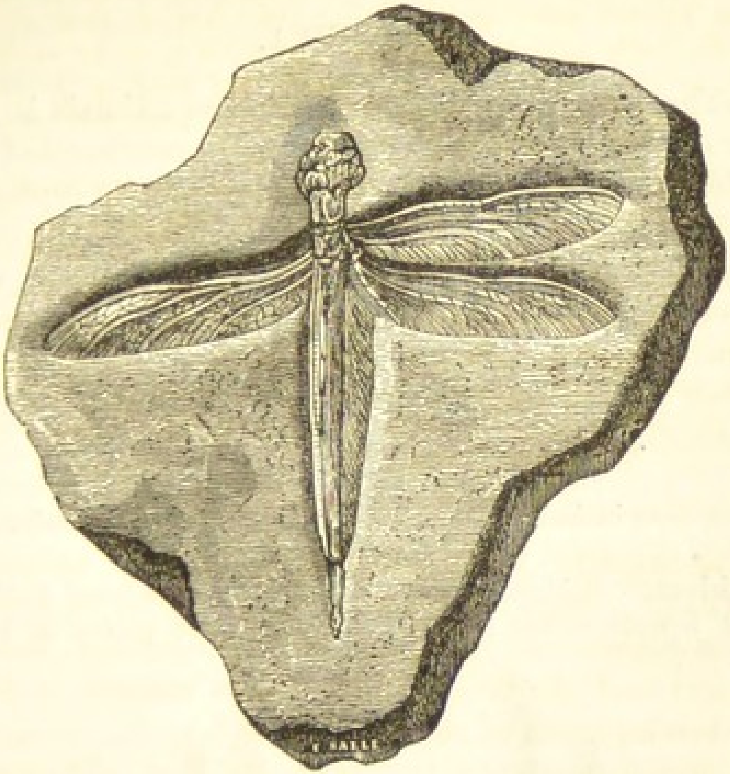


Fig. 197.
FOSSIL DRAGON-FLY (Libellula).

262. **Myriapodes.**—This class differs in a striking manner in several respects, both from insects and arachnida. Its body consists of a vast number of annular segments, to each of which is attached at least one pair of legs. Their general form resembles that of serpents or worms ; but their internal organisation is more analogous to that of insects. The head carries two small antennæ, and two eyes, each composed of an assemblage of ocelli. The mouth, constructed for mastication, has a pair of double-jointed mandibles, with a sort of lip consisting of four divisions, and two pair of appendages, resembling small feet. The feet are terminated by a hook, and on each side of the body is a series of stigmata, or spiracles, being apertures connected with the internal apparatus for respiration, which will be noticed hereafter.

263. This class consists of only two groups, called by naturalists chilognaths or millepedes, and chilopodes, or centipedes. An example of the former is represented in fig. 175, and one of the latter in fig. 176.

The millepede feeds on decaying vegetable matter, and is often found under the bark of trees, curled up like the mainspring of a watch. The

centipede is flat in its body and more membranous and mobile than the millepede. It is carnivorous.

ARACHNIDA.

264.—The tegumentary sheath of these animals is less solid than that of insects ; and the head being confounded with the thorax, the body consists of only two parts, the cephalo-thorax and the abdomen. Their skeleton is distinguished from that of insects by four instead of three pair of legs, all of which are attached to the cephalo-thorax. The legs are brittle, and possess the curious property, when broken, of reproducing themselves. In the front of the cephalo-thorax are placed four pairs of eyes and the mouth.

265. This class includes, besides spiders, scorpions and mites.

266. **Spiders.**—Spiders in general secrete a poisonous fluid, which is fatal to the insects which form their prey. The poison is transmitted

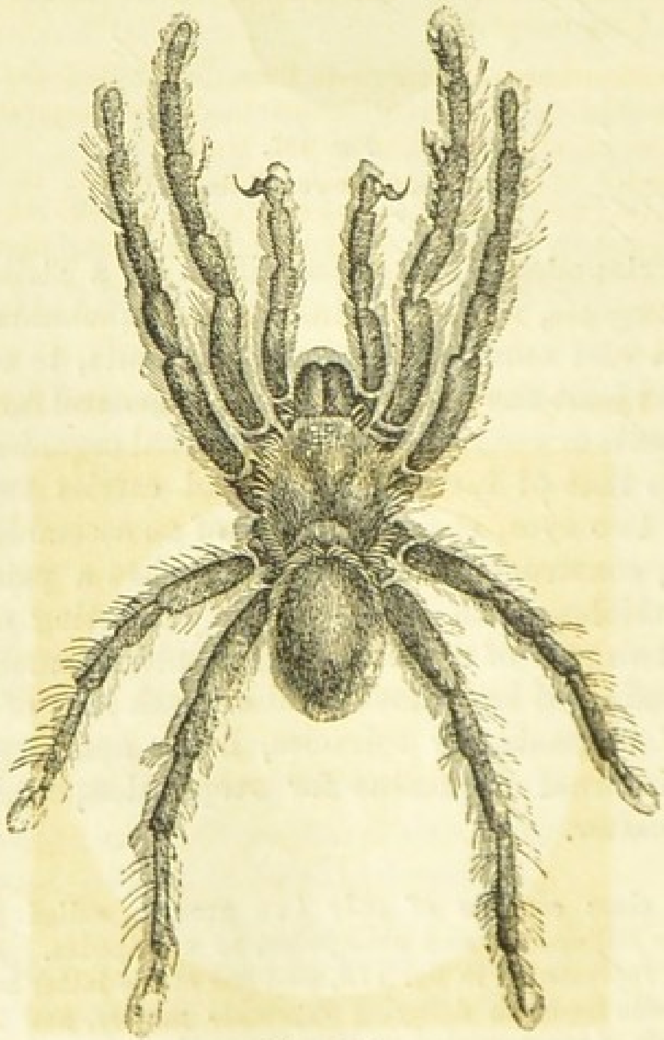


Fig. 198.
MYGALE (SPIDER).

through a perforated fang in the mandibles. In the case of the scorpion, the gland which secretes it is lodged in the extremity of the slender and flexible tail; the wound into which it is poured being inflicted by a curved sting with which the tail is terminated.

267. **Spider's Web.**—One of the most admirable provisions found in the spider is that by means of which the threads of its web are spun. These consist of minute teats at the posterior extremity of the body,—four, six, or eight in number; the orifices in which, for the emission of the threads, are so fine, that a single thread of the web is estimated, by some microscopists, to consist of a thousand, and by others of so many as four thousand distinct filaments.

The web of the common garden-spider consists of two distinct sorts of filaments. Its structure, which is well known, may be described as composed of one system of filaments which radiate from a centre, and another which connect these radii transversely, forming a system of concentrical polygons, one within the other. The transverse filaments are transparent, while the radial ones are opaque. Upon the former the animal deposits innumerable minute globules of a viscid gum, so adhesive, that when it is encountered by a fly, it completely disables the insect, and leaves it at the mercy of its enemy. A web of average size was estimated, by Mr. Blackwall, to contain 87360 of these globules; and a large sized one, from fourteen to sixteen inches in diameter, 120000. Such a net is usually spun in about forty minutes.

268. **Classification.**—Naturalists have distributed the Arachnida in two classes, according to their different modes of respiration; the first possessing a sort of lungs, and the second, tracheæ.

Various species of minute parasitic animals belong to this class. A Brazilian species, for example, called the ixode, attacks dogs and oxen, to the hide of which it attaches itself with such force, that it cannot be removed without detaching the skin. The multiplication of these parasites is such, that they sometimes kill oxen and horses, producing upon them a specific disease.

269. **Itch Insect.**—The insect which produces the itch, belonging to

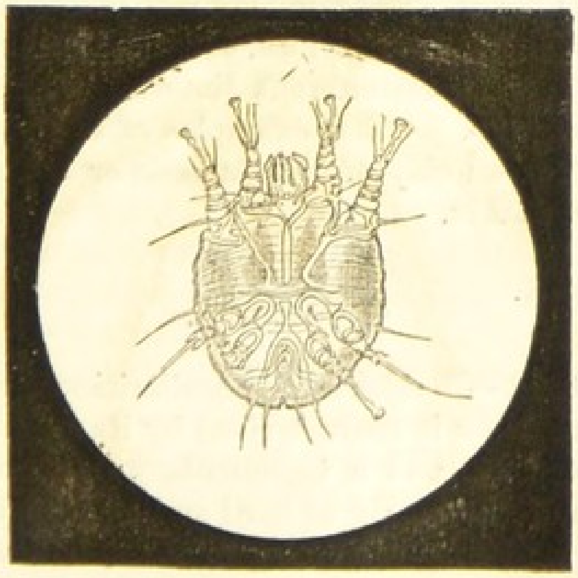


Fig. 199.
THE ITCH INSECT (*Acarus scabiei*).

this class, is represented in fig. 199, magnified in its linear dimensions 120 times, and therefore 14400 times in its superficial dimensions.

270. **Fossil Arachnida** are not less rare than insects,

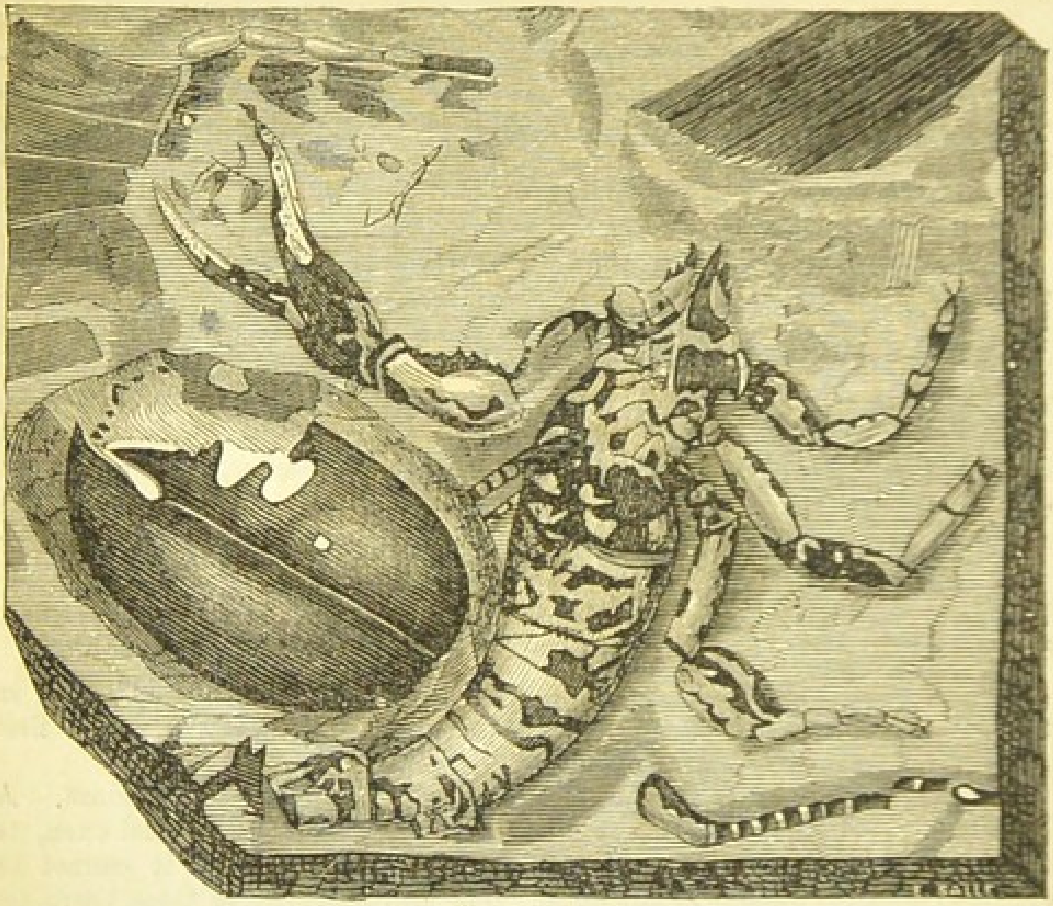


Fig. 200.*
FOSSIL SCORPION (Cyclophthalmus Bucklandi).

although indications of their existence are discoverable in strata of a very early date. The famous fossil scorpion (Cyclophthalmus), found in Bohemia, fig. 200, is an example of this order. It was found in the carboniferous limestone immediately above the Devonian group. Other examples of arachnida have been found in the Oxford clay of the jurassic or oolitic, and in the tertiary group, at Aix.

CRUSTACEA.

271. **Structure.**—Besides some peculiarities of circulation and respiration, this class is characterised by its annulose structure, articulated members, and a tegumentary sheathing—always of considerable, and frequently of hard and calcareous consistency. The types of the group are crabs, lobsters, and crayfish. The

* D'Orbigny.

class receives its name from the shell-like envelope which at once protects it from its enemies and from the shocks of the element in which it lives, and, like the skeleton of the vertebrates, supplies levers and points of reaction for the muscles.

This tegumentary coating, sometimes not very correctly called the external skeleton, is in fact the analogue of the epidermis, a membrane similar to the derma being found under it, within which the organs are inclosed.

This casing, being rigid, hard, and inelastic, and therefore incapable of yielding to the growth of the body within it, is cast from time to time as the body is enlarged, just as reptiles

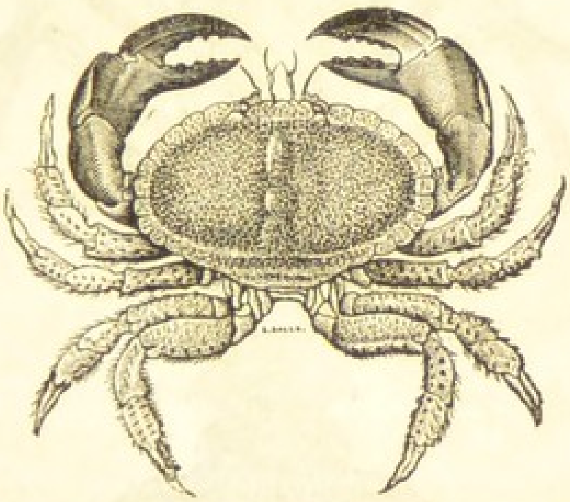


Fig. 201. R. An.
THE COMMON CRAB (Cancer pagurus).

and the larvæ of certain insects cast their skins. The animal issues from its shell without sustaining the least derangement of its form, and the exuviæ which it thus abandons retains its appearance and shape so perfectly, that it is often mistaken for the animal itself deprived of life. On issuing from the exuviæ, the new shell is already formed around it, but still soft in its consistency. The timidity of the animal at such times shows its consciousness of the want of its usual armour. After a few days, however, the new shell hardens, and the creature recovers its habits.

The annulose segments of the body are very variously connected in different species. In some they are articulated, so as to allow of great flexibility. In others they are connected together, their separate form being only indicated by the ridge or groove which limits them; and in others they are so indistinguishable, that the annulose structure is established more by

analogy than by external indications. Hence, it will be evident that among these animals there are great diversities of form, as

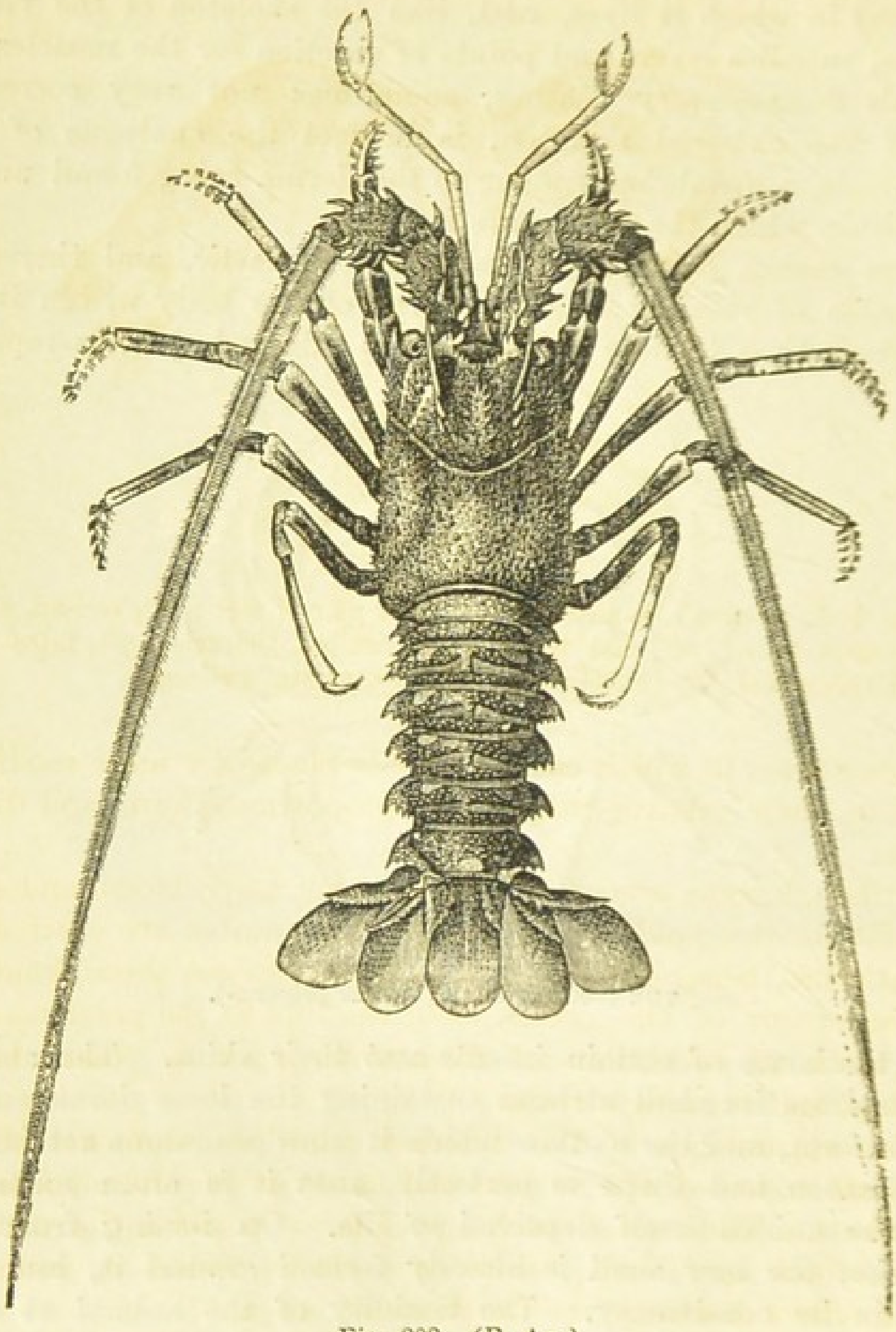


Fig. 202. (R. An.)
THE SPINY LOBSTER (Palinurus vulgaris).

will be apparent on comparing specimens chosen from different species; as, for example, the crab (fig. 201), the lobster (fig. 202), and the squilla (fig. 203).

A close and accurate analysis of the structure of the various species will, however, render it manifest that Nature, in accordance with the general spirit of the creative laws which she has prescribed to herself, has in this case, as in others, worked

upon one simple and general plan, reproducing in all cases the same organic elements, and adapting them to the varying

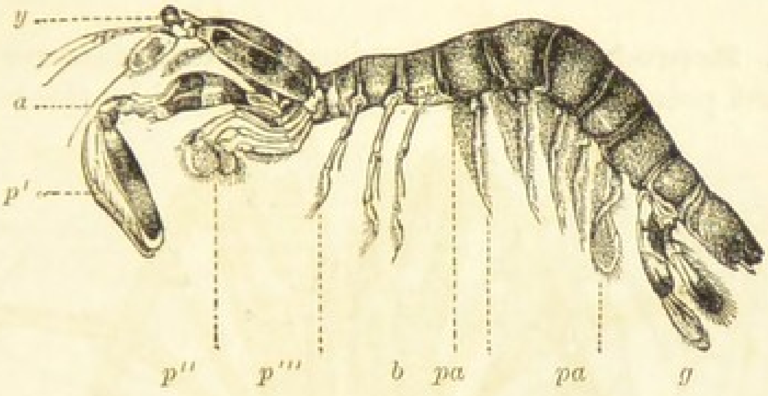


Fig. 203. (R. Ar.)

THE SQUILLA.

Fig. 203. *y*, eyes ; *a*, antennæ ; *p'*, first pair of feet ; *p''*, second, third, and fourth pair ; *p'''*, last three pairs, called thoracic ; *pa*, false feet, called abdominal ; *b*, bronchiæ, or gills ; *g*, caudal swimmer.

circumstances in which each species is placed by mere modifications in their relative magnitude, proportion, form and disposition.

Although some species of Crustacea are amphibious, and some inhabit the dry land, by far the greater number are created for aquatic life, being diffused in countless numbers throughout the entire extent of the ocean, from the line to the polar seas, as well as in all collections of fresh water, such as ponds, lakes, ditches, and running streams.

The appendages of the different annulose segments of the body are endowed with various and most curious and unexpected functions. Thus some such appendages perform the duty of jaws, others carry eyes, others ears, others feelers or antennæ, while others discharge the functions of lungs.

The squilla, fig. 203, and the cray-fish, figs. 204, 205, and the prawn, fig. 206, present instructive examples of this.

In general, the appendages of the foremost segments exercise the functions of the senses, the succeeding ones those of prehension and mastication ; the next, those of locomotion ; the next being variously endowed in different species, but exercising mostly the functions of respiration and reproduction ; and the last, those of nutrition.

272. **The food** of Crustacea consists generally of animal substances, some having organs of mastication adapted to solid food, and others organs of suction adapted to fluids.

273. **Reproduction.**—All animals of this class are endowed with that peculiar power of growth expressed by the term repro-

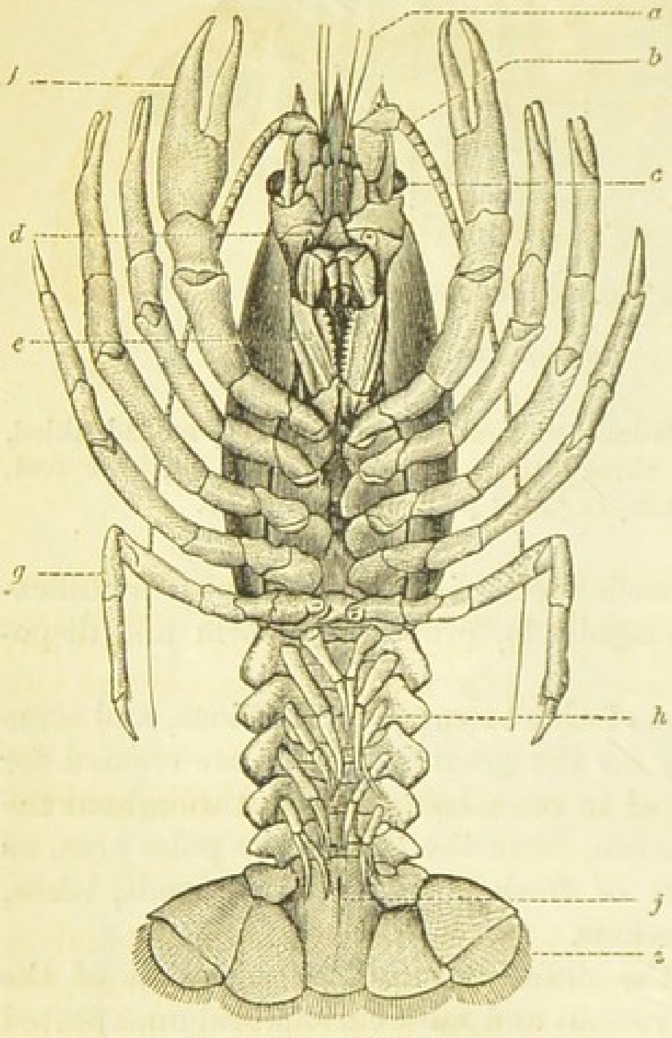


Fig. 204.* (R. An.)
THE CRAY-FISH.

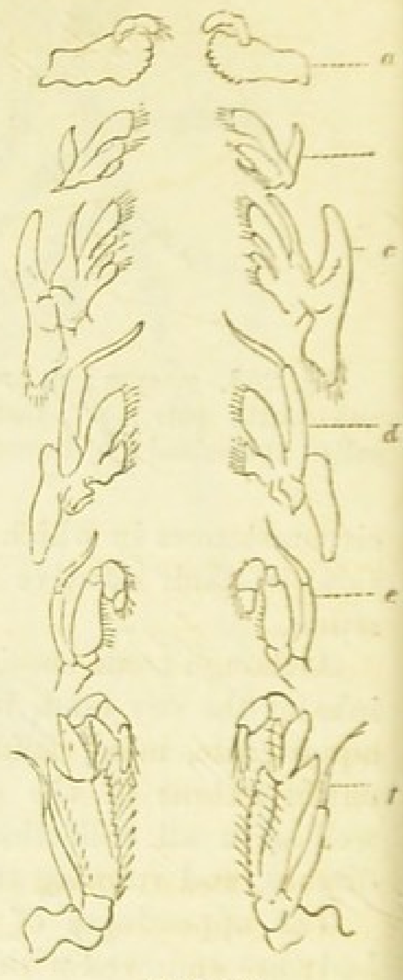


Fig. 205.
ITS MASTICATING APPARATUS.

Fig. 204. The under part of the cray-fish; *a*, first pair of antennæ; *b*, second pair; *c*, eyes; *d*, auditory tubercles, or ears; *e*, external feet, endowed with the functions of jaws; *f*, first pair of thoracic legs; *g*, fifth pair; *h*, false, or abdominal feet; *i*, caudal swimmer; *j*, anus.

Fig. 205. Its masticating apparatus, consisting of six pairs of appendages, separately shown. *a*, mandibles; *b*, *c*, first and second pair of jaws; *d*, *e*, *f*, three pair of feet, endowed with the functions of jaws.

duction, in virtue of which a member cut or torn off will be replaced by the mere process of growth. When a leg of a crab,

* Edwards.

for example, is fractured, the animal throws off the broken limb, after which the hæmorrhage ceases and a new limb begins to make its appearance, the growth of which is at first slow;

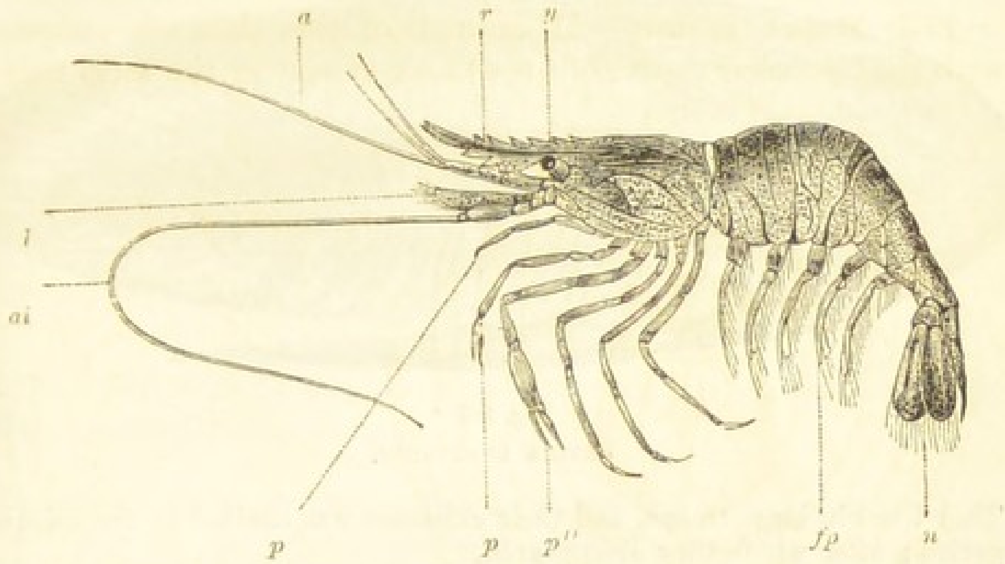


Fig. 206.*
THE PRAWN.

Fig. 206. *a*, first pair of antennæ; *ai*, second, or inferior pair; *l*, lamellated appendage, covering their base; *r*, rostrum, or frontal prolongation of the carapace; *y*, eyes; *pm*, external feet jaws; *p'*, first pair of thoracic legs; *p''*, second pair; *fp*, false abdominal legs, endowed with the functions of swimmers; *n*, caudal swimmer.

but becomes more rapid after the next moult, and soon assumes its full proportions.

274. **Fossil Crustacea**, like reptiles and fishes, are found in all the geological periods since the first appearance of animal life on the earth. About forty genera have been found in the lowest strata of the secondary rocks, two in the trias, thirty-six in the oolite, six in the cretaceous, and twenty-four in the testaceous rocks; from which it would seem that the prevalence of the Crustacea has been decreasing since the earliest geological epochs. Such a conclusion would, however, be opposed to the fact, that the number of genera existing amounts to two hundred.

Among the most remarkable of the extinct Crustacea are the *trilobites*, an order which consisted of an oblong body, divided transversely into three parts, and also longitudinally into the same number of lobes. The comparison of the forms of these animals with those of existing Crustacea

* D'Orbigny.

render it probable that they dwelt in the depths of the sea far from coasts floating on their back, and never resting, inasmuch as their feet could not retain them stationary, and movement was necessary for their respiration.

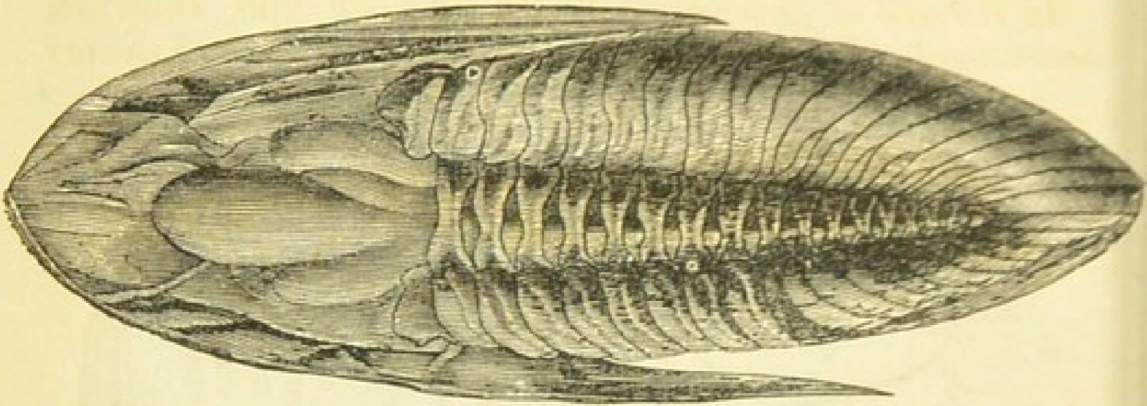


Fig. 207.*
OGYGIA GUETTARDI.

They lived in large troops, and their existence was limited to the Silurian period; after which they disappeared.

In fig. 207 is shown a specimen of this order—the *Ogygia guettardi.*

WORMS.

275. This class, denominated *Annelids,* is characterised by a peculiar nervous and vascular system. Its types are the common earthworm and the leech.

The body is in general very soft, and divided transversely by numerous wrinkles or grooves. Sometimes there is a distinct head, but oftener that part is confounded with the body. The annulose segments are in most species supplied

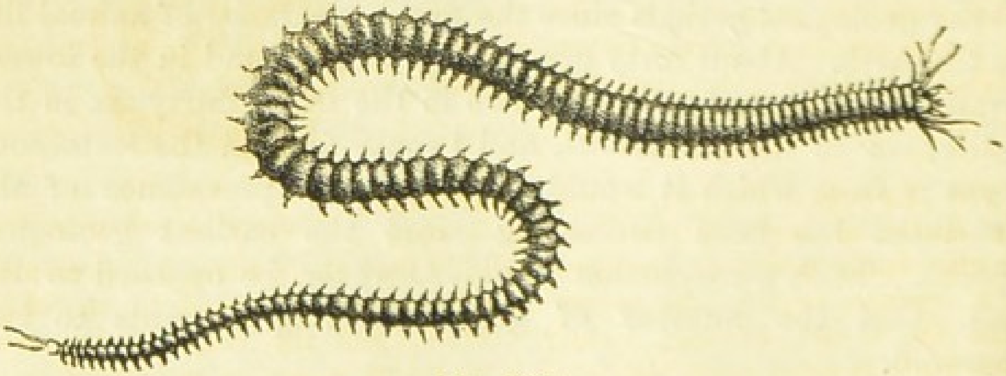


Fig. 208.†
THE NEREIS.

* D'Orbigny. † Edwards.

with the analogues of legs in the form of hooked bristles, fig. 208, which serve the animal for locomotion, and sometimes for defence.

In the case of annelids, such as leeches, fig. 209, which are destitute of those bristles, there is a sucker at each extremity

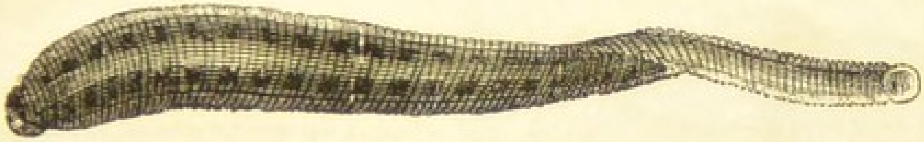


Fig. 209.*
THE LEECH.

of the body, which, combined with the contractile power of the body, serves for locomotion.

Several of the sea-worms provide for themselves a habitation consisting of a long tube, formed of calcareous matter secreted by their proper organs, and sometimes formed of particles of sand or gravel agglutinated together. Examples of the former are presented in the case of the twisted tubes which are seen attached to dead shells dredged from the bottoms of arms of the sea. These tubes are the habitations of sedentary worms, called *Serpulæ* (fig. 210). If the tubes be placed in a vessel of sea-water while the animals still live, a curious and pleasing spectacle will be witnessed. The mouth of the tube will be first seen to open by an exquisitely-constructed door, which will be raised by the creature, from which it will cautiously protrude the head and anterior part of its body, spreading out at the same time two gorgeous, fan-like expansions, of a rich scarlet or purple colour, which float elegantly in the surrounding water, and serve as organs of respiration.

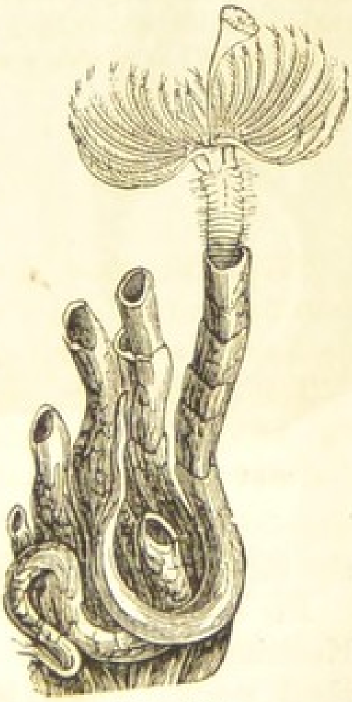


Fig. 210.
GROUP OF SERPULÆ.

276. **Leech.**—The instrument of suction of the medicinal leech consists of small semicircular horny saws, so arranged radially that their edges are presented to a common centre. No sooner is this sucker implanted in the skin, than the mouth becomes tightly everted, and the edges of the saws thus made to press upon the tense integument, a sawing movement being at the same time given to each, so that they cut their way to the sluices of blood beneath. Nearly the entire body of the animal consists of a series of chambers, into which the blood thus taken is received. These are eleven in number, perfectly distinct; and in the first eight, the blood may

* Jones, Natural History, p. 313.

remain for months unchanged in colour or fluidity, the creature merely allowing so much to pass into the alimentary canal as is necessary to preserve its existence. Hence the repugnance of the animal to repeat the operation until the store of food with which it has been gorged is consumed.*

277. **Fossil Annelids** of the genus of Serpulæ are found in all the rocks, from the Devonian upwards, fig. 211. Remarkable

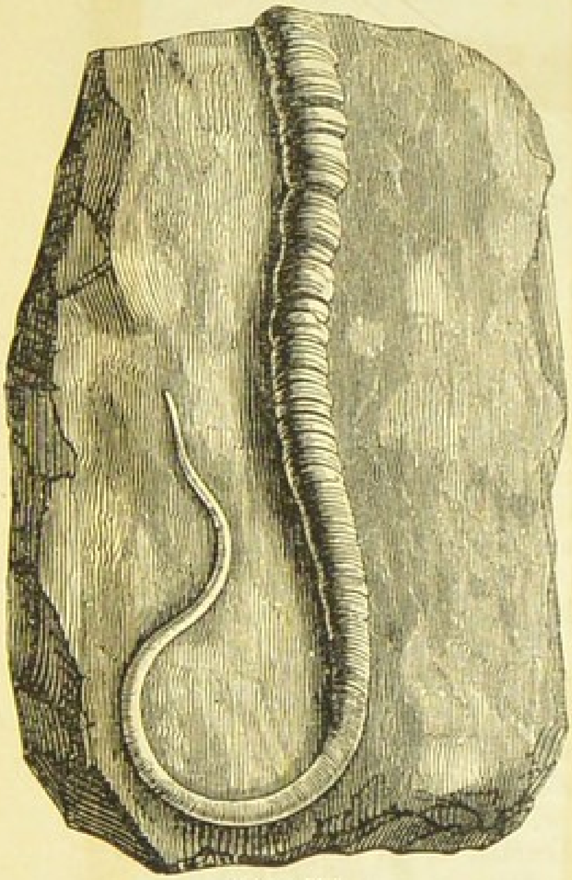


Fig. 211.
SERPULA FLAGELLUM.

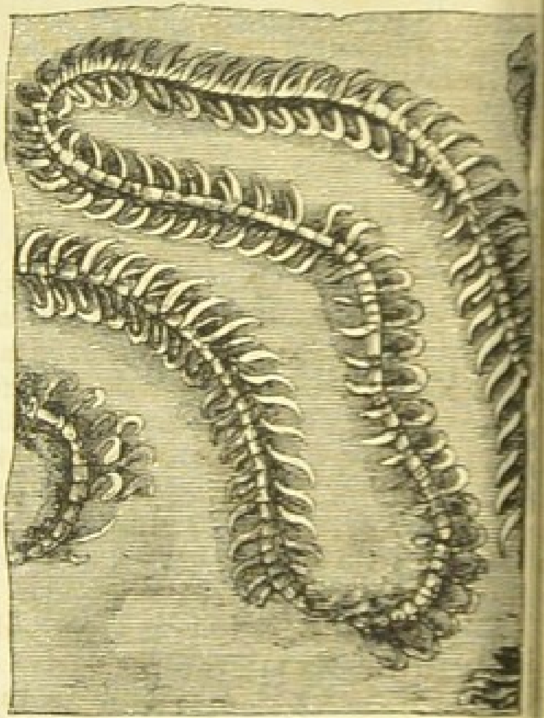


Fig. 212.†
NEREITES CAMBRIENSIS.

imprints of the dorsi-branchial order have been discovered in the Silurian rocks, a specimen of which is shown in fig. 212.

In connection with this division may be mentioned the Helminthes or Nematoids, and the Cestoids or Tænoids, intestinal worms which live as parasites in the bodies of other animals, and are thence called by the generic name Entozoa. Of these the tænia, or solitary worm of the human body, is an example. Their organisation presents no character of interest to claim any extended notice in this work.

ROTIFERA.

278. This division, one of the species of which is well known

* Jones, Natural History, vol. i. p. 322. Owen, Lectures, p. 133.
† D'Orbigny.

as the *wheel animalcule,* was classed among the Infusoria, and supposed to be a mere mass of animated jelly, until the improved powers of the microscope displaying its true structure, proved it to be a true annelid, of microscopic minuteness.

The body, which is translucent, is shown highly magnified in fig. 213. The mouth is placed at the anterior extremity, round which are ranged vibratile cilia, the rotatory motions of which produce the eddies of water indicated in the figure. The mouth is surrounded by powerful muscles, and armed with lateral jaws. The alimentary canal is straight, and, extending from one end of the body to the other, has an enlargement near the middle, which constitutes the stomach. Various muscles, salivary glands, ovaries, and a nervous apparatus, have been discovered in the organisation of these minute creatures.

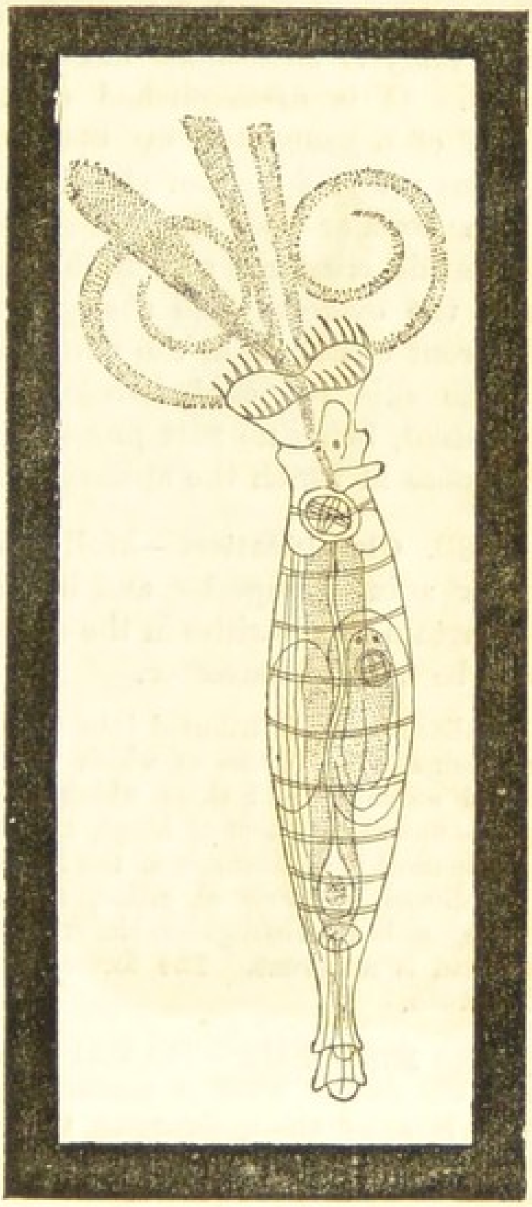


Fig 213.
THE ROTIFERA.

The rotifera feed upon a still more minute tribe of animals called *polygastrica.* They possess an instrument by which they can attach themselves to one spot, and feed at ease upon the nutriment which the eddies produced by the cilia surrounding the mouth constantly draw into it.

They are remarkable for their tenacity of life. Spallanzani kept them in a state of torpor for four years, after which, being immersed in water, they recovered their vitality. He further showed that they could be revived, after a long succession of torpid intervals, by alternately drying and moistening the same individual. He tried this experiment sixteen times on the same assemblage of animalcules. After such inhumation, a gradually decreasing number were restored to life ; and after the sixteenth none revived.

MOLLUSCA.

279. This division of the Animal Kingdom, which takes its name from the softness* of the body common to all the individuals

* Molluscus, soft.

which compose it, is distinguished from the superior orders by the absence of either the internal skeleton of the vertebrates, or the tegumentary skeleton of animals of annulose structure. The body is sometimes naked and sometimes covered with a shell. It is distinguished from the animals below it in the scale of organisation by the symmetrical distribution of its organs round a median plane.

In popular use, the term shell-fish is applied indifferently to certain crustacea and mollusca,—to the lobster, for example, and the oyster. The shelly envelope has, however, a totally different character in the two cases. In the Crustacea the shell is the skin rendered horny or calcareous. In the Mollusca the shell, being no part properly of the body, is the habitation or house in which the animal dwells.

280. **Classification.**—Mollusca are distinguished also from other animals superior and inferior, as well as from each other, by certain peculiarities in the nervous and vascular systems which will be noticed hereafter.

Mollusca are distributed into two classes, according to the structure of their shells. Those of which the shell consists of a single piece are called *univalve*, and those which have a shell composed of two similar pieces united by a sort of hinge, are called *bivalve.*

The snail is an example of the former, and the oyster of the latter.

Mollusca, properly so called, are also resolved into two classes—one having a head distinguishable from the body, and the other in which no head is apparent. The former are called *encephala*, and the latter *acephala.*

The Encephala.—The head is supplied with appendages and eyes; and the animal, when it possesses a shell, is invariably univalve. The class is sub-divided, according to the position and arrangement of the members of locomotion, into *cephalopodes*, having the feet surrounding the head; *pteropodes*, having the feet like wings at each side of the neck, their form being that of paddles or fins; and, in fine, the *gasteropodes*, of which the members, having either the form of feet, or of a fleshy disc, are placed upon the inferior surface of the body.

The Acephala, in which there is no distinct head, are always supplied with a bivalve shell.

Besides these, are two subdivisions called the *tunicata* and the *ciliated polypes;* the former having a heart and vascular system, of which the latter is destitute.

281. **Cephalopodes** exhibit the most fantastic varieties of form. The head, placed in the inferior surface of the body, and surrounded by the feet, tentacula, or organs of locomotion, is trailed along while the animal moves, An example of this class is presented in the common poulpe or octopus, fig. 214, where the inferior surface is shown, the eyes presenting a remark-

able appearance. There are here four pair of tentacula symmetrically disposed round the head, which serve equally as members of locomotion and prehension. By these organs the poulpe is rendered a most destructive

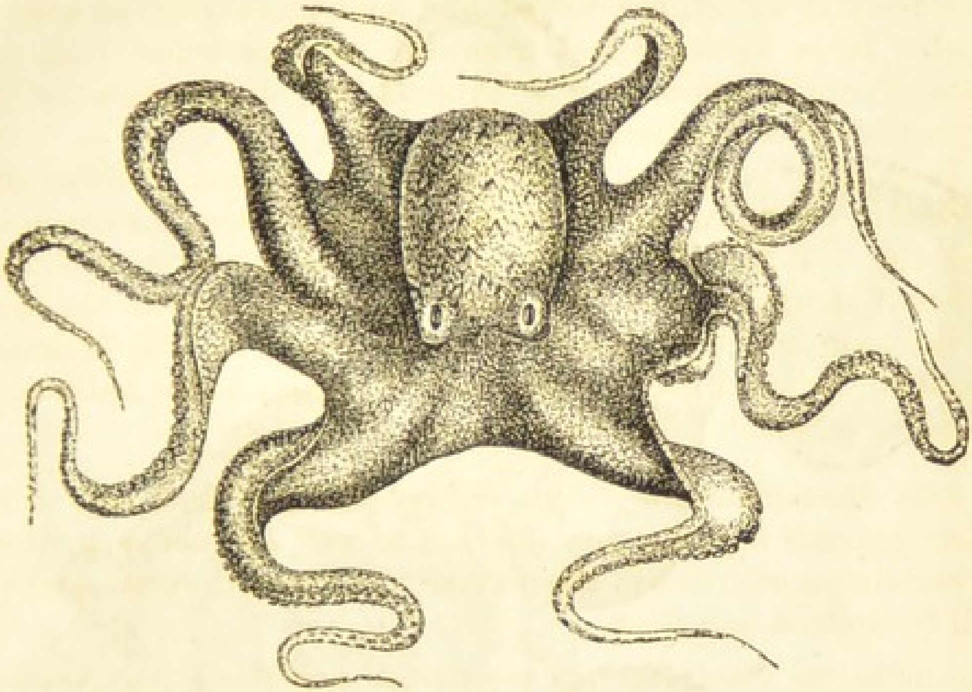


Fig. 214.*
THE COMMON POULPE OR OCTOPUS.

animal, for neither superior strength, nor agility, nor defensive armour, can save its victim. Not fewer than 120 suckers, as efficacious as the surgeon's cupping-glass, are disposed around each of the eight tentacula. When the poulpe only touches its prey, so that a few of these suckers take effect, there is no escape for it. Its swiftness, however great, is unavailing, since it carries its enemy with it. The shell of the crab or lobster is an ineffectual defence, for it is easily broken in pieces by the hard and crooked weapons of the poulpe. †

The cuttlefish, another example of the cephalopodes, has five pair of tentacula. In some species, as, for example, the *Argonaut*, or paper nautilus, fig. 215, one pair of these is terminated in a membranous enlargement, which was supposed to be used as a sail when the animal floats on the surface, while the remaining pairs served the purpose of oars. This, however, pretty and attractive as the supposition is, appears to be unfounded. The animal never uses its tentacula for such a purpose, and moves through the water backwards, like other cuttlefish.

282. **Fossil Cephalopodes** are exceedingly numerous; but of all the genera hitherto discovered, one only, that of the nautilus, has come down to the present times.

These fossils appear in great numbers in the lower strata of the secondary rocks, are few in the lias and oolite groups,

* Edwards. † Jones' Outlines of the Animal Kingdom, p. 431.

re-appear in great numbers again in the cretaceous, and disappear once more in the tertiary rocks.

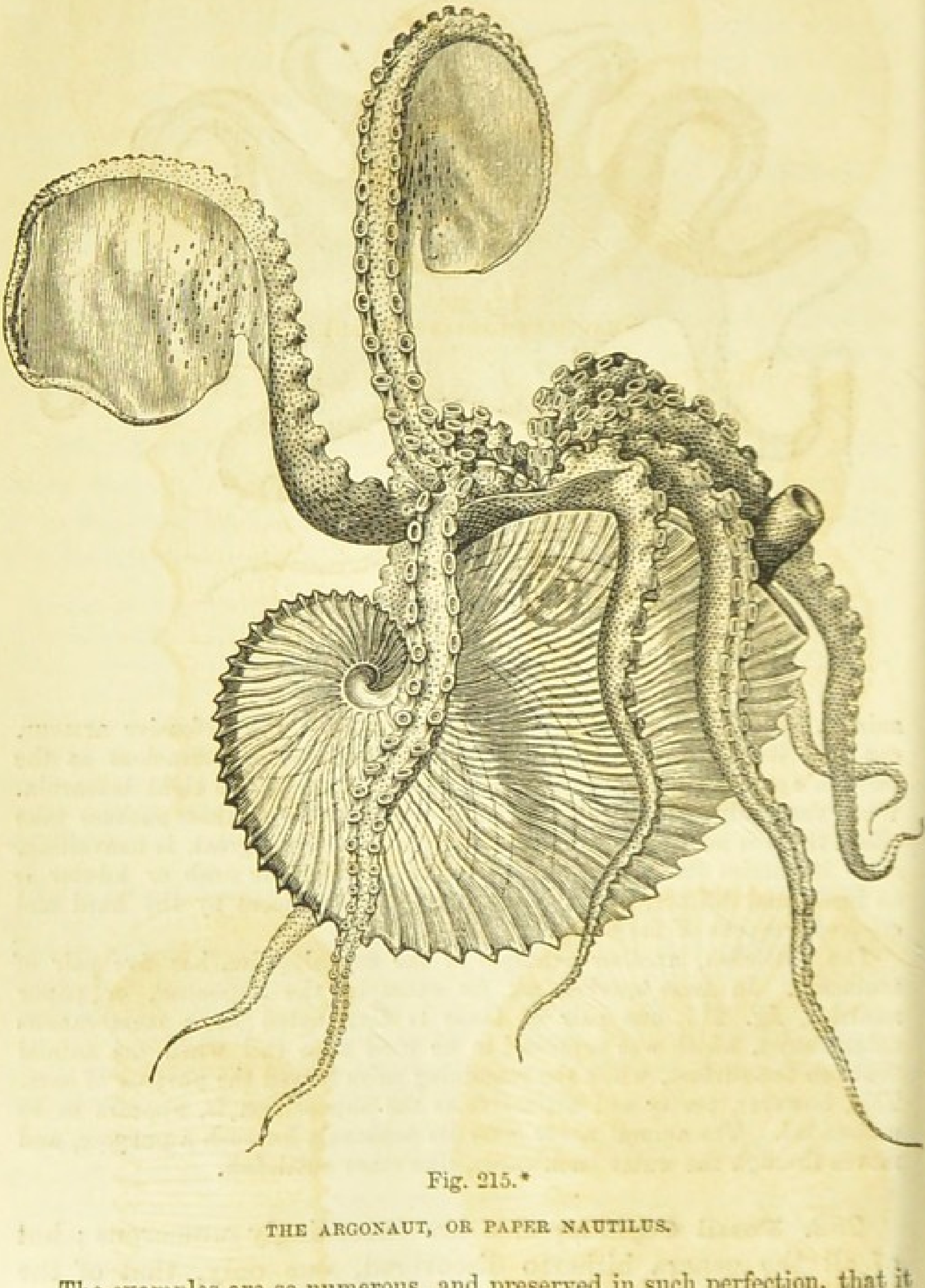


Fig. 215.*

THE ARGONAUT, OR PAPER NAUTILUS.

The examples are so numerous, and preserved in such perfection, that it is difficult to select any in preference to another, as illustrations of their forms. The Nautilus, the only surviving genus of the tentaculiferous cephalopodes in the first periods of animal life, had nearly the form

* Edwards.

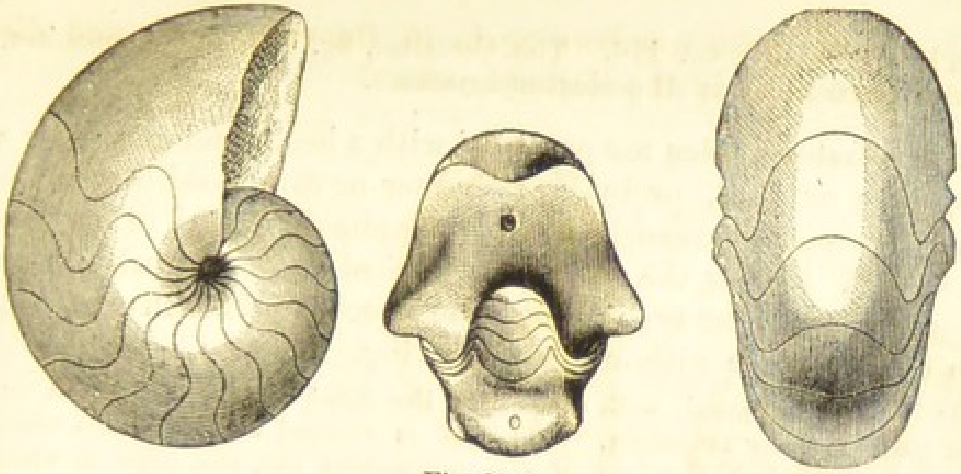


Fig. 216.*
NAUTILUS DANIANS (Fossil).

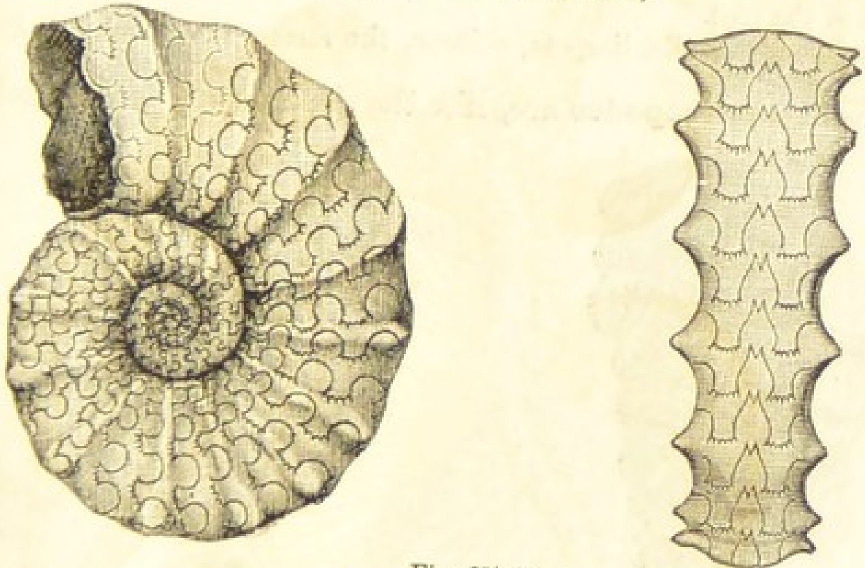


Fig. 217.*
CERATITES NODOSUS (Fossil).

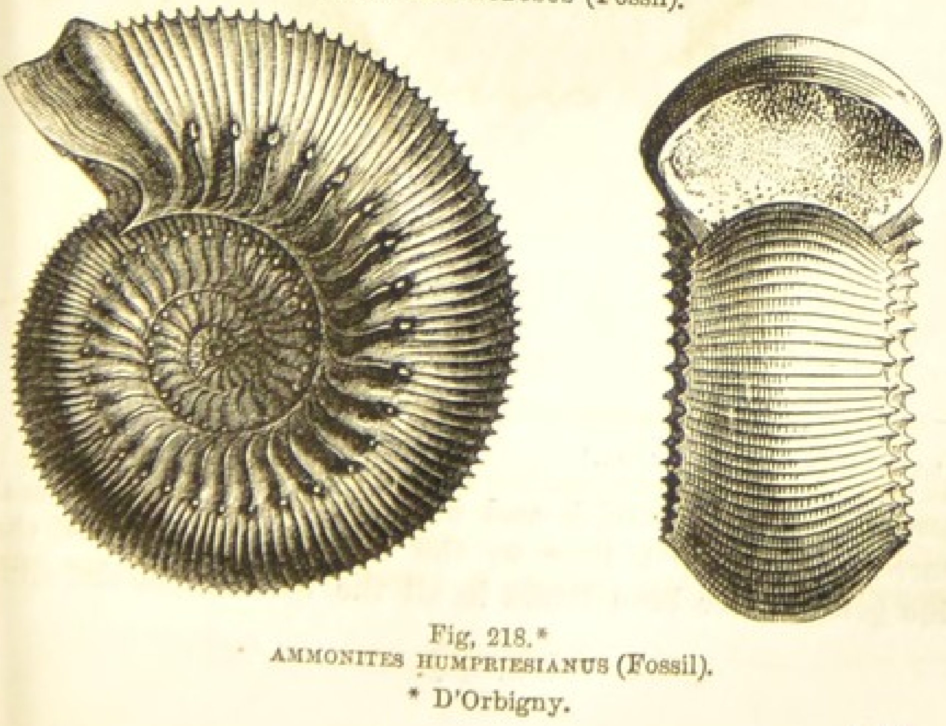


Fig. 218.*
AMMONITES HUMPRIESIANUS (Fossil).

* D'Orbigny.

which it still retains, fig. 216. The Ceratites, fig. 217, and Ammonites, fig. 218, are familiar to all geological amateurs.

283. **Gasteropodes** are provided with a head, and moved by a fleshy disc or foot, or by a swimmer or fin placed under the belly. This class consists chiefly of animals lodged in an univalve shell, having the form of a conical spiral, of which the common snail is the type ; but some species, of which the slug is an example, are without that covering.

The body is elongated, with a head in the front part, having from one to six pair of fleshy tentacula. The back is covered with a mantle which extends backward, in the form of a membraneous sac, the edge of which secretes the matter which forms the shell. The belly is covered by the fleshy mass of the foot.

This class includes snails, limpets, chitons, the vermetus, the murex, &c.

284. **Fossil Gasteropodes** are, like the Cephalopodes, extremely

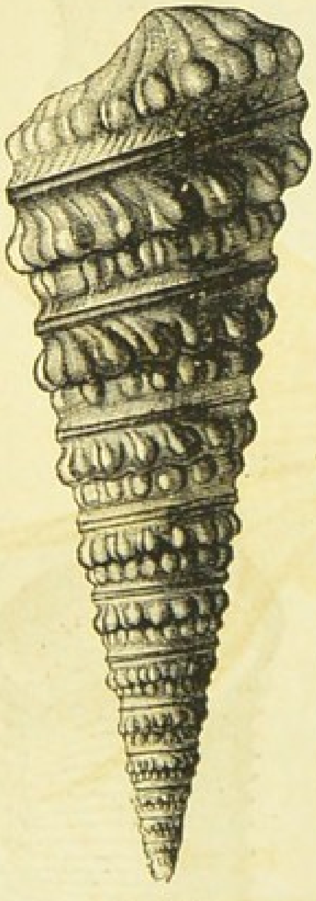


Fig. 219.
MURCHISONIA BIGRANULOSA.*

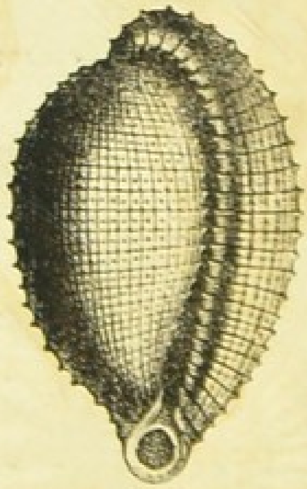


Fig. 220.
CYPRÆA ELEGANS.*

numerous. The terrestrial and fluvial genera have in general appeared for the first time in the tertiary period ; but the marine genera have been found in all the rocks from the silu-

* D'Orbigny.

rian upwards, and in gradually increasing numbers. They were, therefore, among the earliest manifestations of animal life on the globe ; and what is remarkable is, that most of the genera, including even those of the silurian period, still survive.

The close analogy of these ancient forms with the existing species will be manifest by some examples taken from among the countless numbers of fossil shells collected by geologists.

A fossil shell from the permian group is shown in fig. 219, and one found in all the tertiary beds in fig. 220.

One of the genera which first appears in the middle strata of the creta-

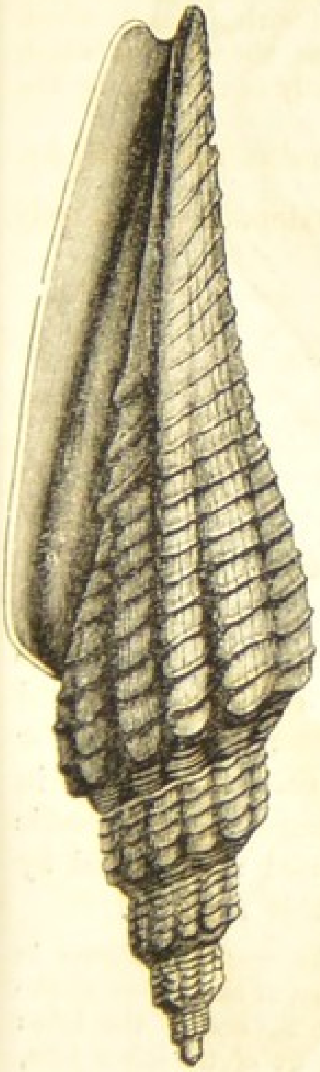


Fig. 221.

VOLUTA ELONGATA.*

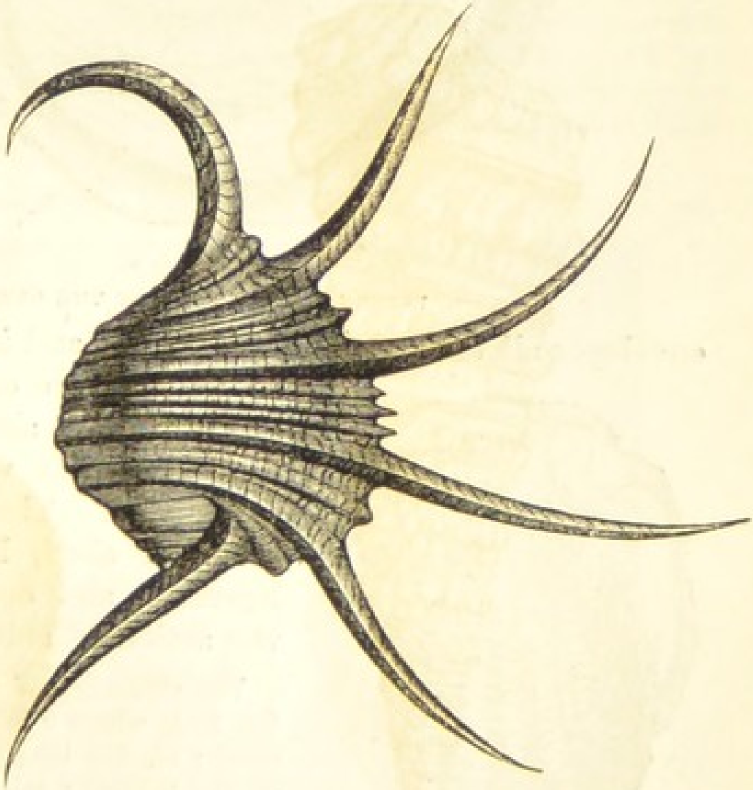


Fig. 222.

PTEROCERA OCEANI.*

ceous group is shown in fig. 221, and one which begins in the middle of the oolite, in fig. 222.

285. **Pteropodes** are sometimes provided with a shell, and

* D'Orbigny.

sometimes destitute of that covering. Their structure presents but little interest.

286. **Acephala**, of which the oyster is the type, have a body enveloped in a mantle, as a book is enclosed by its binding. The skin connected only on one side, forms a large fold which

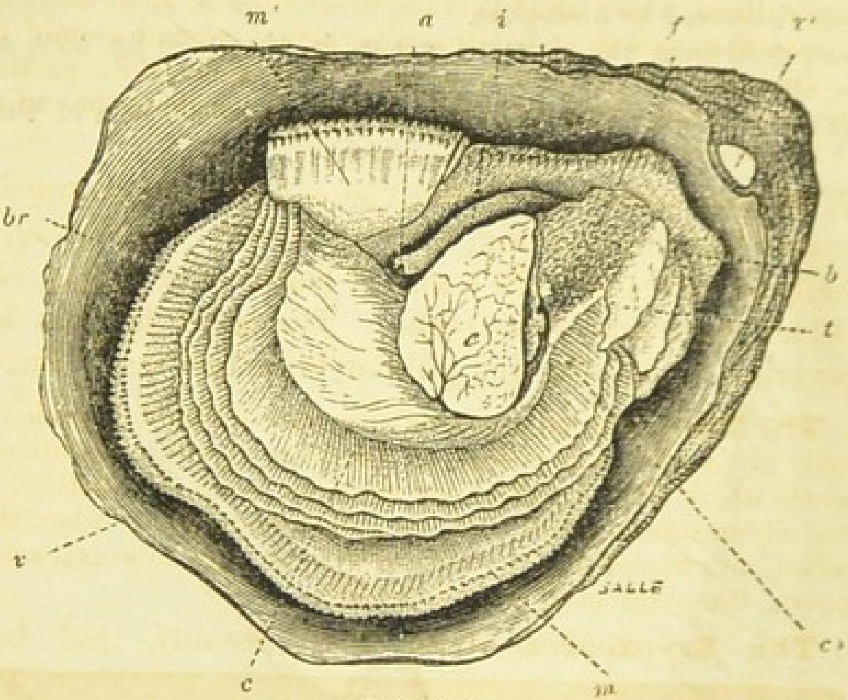


Fig. 223.*
INTERNAL STRUCTURE OF THE OYSTER.

envelopes all the organs of the body, and is sometimes united so as to leave openings only before and behind, to allow the entrance and escape of the water necessary for respiration. The body is enclosed in a bivalve shell, hinged by an elastic ligament, and opened and closed by the action of suitable muscles.

Fig. 224.*
SHELL OF THE PEARL OYSTER.

The structure of the oyster is shown in fig. 223, where *v* is one of the valves of the shell; *v'*, the hinge; *m*, one of the lobes of the mantle; *m'*, part of the other lobe, folded back; *c*, adductor muscle; *br*, branchia or gills; *b*, mouth; *t*, tentacula; *f*, liver; *i*, intestines; *a*, anus; *h*, heart. Fig. 224 shows the shell of the pearl oyster.

The Acephala are resolved by naturalists into two orders: 1°, the *Lamellibranches*, which include the oyster, the mussel, the scallop, and the cockle; 2°, the *Brachiapodes*, or arm-footed, which derive their name from two fleshy arms which replace the feet, of which the terebratula is an

* Edwards.

example. This latter order consists of few existing species, and these dwell at great depths in the sea, being generally brought up from depths of sixty to one hundred fathoms. Professor Owen remarks, in reference to the Brachiapodes, that their respiration and nutrition at such depths are subjects suggestive of interesting reflections, and lead one to contemplate with less surprise the great strength and complexity of some of the minutest parts of the frames of these diminutive creatures. In the unbroken stillness which must pervade those abysses, their existence must depend upon their power of exciting a perpetual current around them, in order to dissipate the water already laden with their effete particles, and to bring within the reach of their prehensile organs the animalcules adapted for their sustenance.

287. **Molluscoids** form a subdivision of Mollusca, consisting of two groups, the *Tunicata* and the *Bryozoares*. The former, instead of a shell, are invested with a sort of leathery covering, or tunic, from which they take their name. The latter have a less perfect covering or mantle, the gills or branchiæ being uncovered.

288. **The Tunicata** have a vascular system which is attended with the peculiarity of an alternate change of direction of the circulation, so that the vessels which are arteries at one time are veins at another, and *vice versâ*, a circumstance which will be better understood when the reader has studied our chapter on the vascular system. In this class are included the biphora, the pyrasomes, and the ascidia.

289. **The Bryozoares** which, until recently, had been con-

c b a

Fig. 225.
PLUMATELLÆ.*

founded with the most simple Polypes, have organs of aquatic respiration,

* Edwards.

consisting of a circle of tentacula around the mouth, which are supplied laterally with vibratile cilia, as may be seen in the example of the plumatella, fig. 225; *a*, a group of plumatellæ in their natural size; *b*, others magnified, and seen in different positions; *c*, the anus.

In this case there is circulation without a heart, the blood moving between the viscera and the mantle. The inferior part of the mantle is in general hardened, so as to form a sort of tube or cell, sometimes of horny and sometimes of calcareous consistency, into which the animal can retire. In general these animals, which are of almost microscopic minuteness, live assembled in groups more or less considerable. They mostly inhabit the sea, but some of them are found in fresh water, among which are included the plumatella, common enough in ponds.

290. **Fossil Acephala** are infinitely great in number and various in form, and prevail through all the geological periods, from the silurian to the uppermost tertiary. Of the Lamellibranchiæ most of the genera still survive, a few only becoming extinct in each group of rocks. A less proportion of the Brachiopodes and Bryozoares survive. In all, however, the number of species extinct is very great. How closely these molluscs of the earlier epochs of the globe resembled in their structures the living species, will be seen by reference to a few of the numerous examples of fossil species which have been recovered.

291. **The Spondylus**, fig. 226, of which there are forty-five fossil

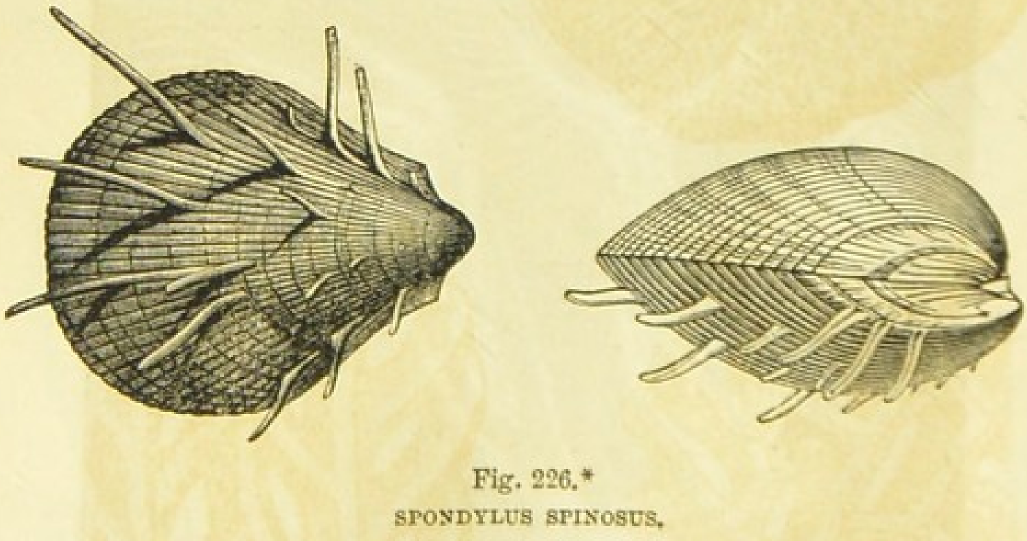


Fig. 226.*
SPONDYLUS SPINOSUS.

species, first appears in the lowest stratum of the cretaceous group, and presents an example of the fossil Lamellibranchiæ.

292. **The Pentamerus**, fig. 227, of which there are twenty-one fossil species, is an example of the Brachiopodes. This species is first seen in the lowest strata of the silurian group, and becomes extinct after the

* D'Orbigny.

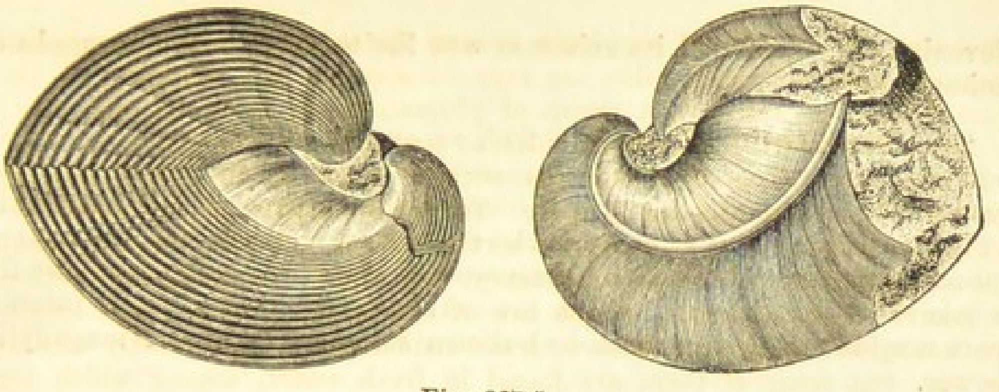


Fig. 227.*
PENTAMERUS KNIGHTII.

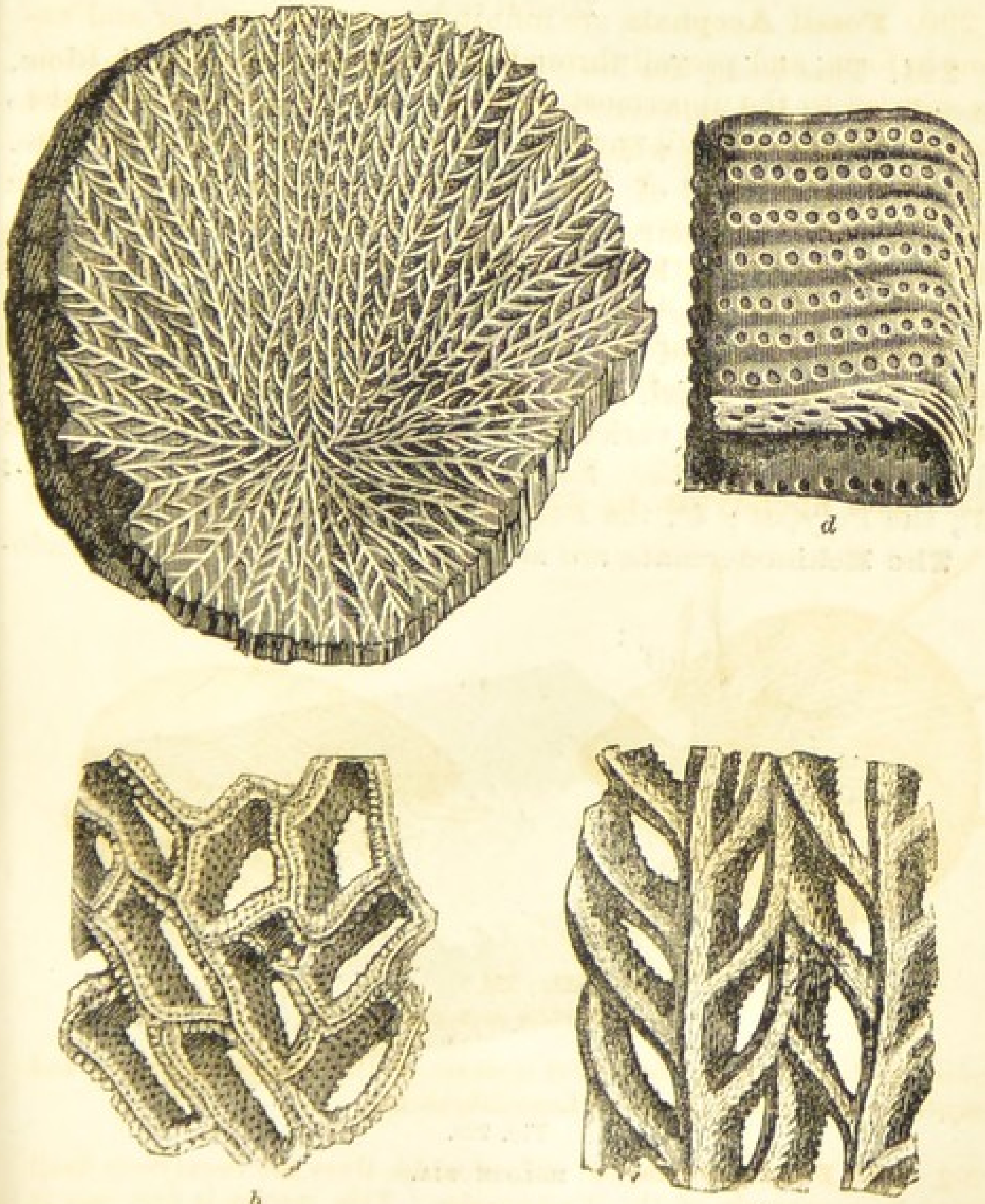


Fig. 228.*
RETICULIPORA OBLIQUA.

* D'Orbigny.

devonian period, so that its existence was limited to the earliest epochs of animalisation.

293. **The Reticulipora**, fig. 228, an example of the Bryozoares, is an extinct genus Retepora, of which there are five fossil species known; the first in the middle strata of the oolites, and the others in the upper strata of the cretaceous group. In this the meshes are formed of high vertical laminæ, supplied with cells by transverse lines on each side; *a*, shows the whole in its natural size; *b*, the external part magnified; *c*, the internal part magnified; *d*, the laminæ as shown with a still higher magnifying power.

ZOOPHYTES.

294. This being the lowest branch of the animal kingdom, may be regarded as constituting the transition from animal to vegetable life, from which character it has received its name. The organs, instead of being disposed symmetrically on each side of a median plane, are grouped around an axis, or centre, so as to give to the body a radiated or spheroidal form. The peculiarity of the nervous system will be explained hereafter.

A great variety of structure prevails among these animals, many species of which more resemble vegetables than animals. According to these varieties of form, they are distributed in five classes: 1°, the Echinodermata; 2°, the Acalepha; 3°, the Polypes; 4°, the Polygastria; and 5°, the Sponges.

The Echinodermata are animals having a thick skin, some-

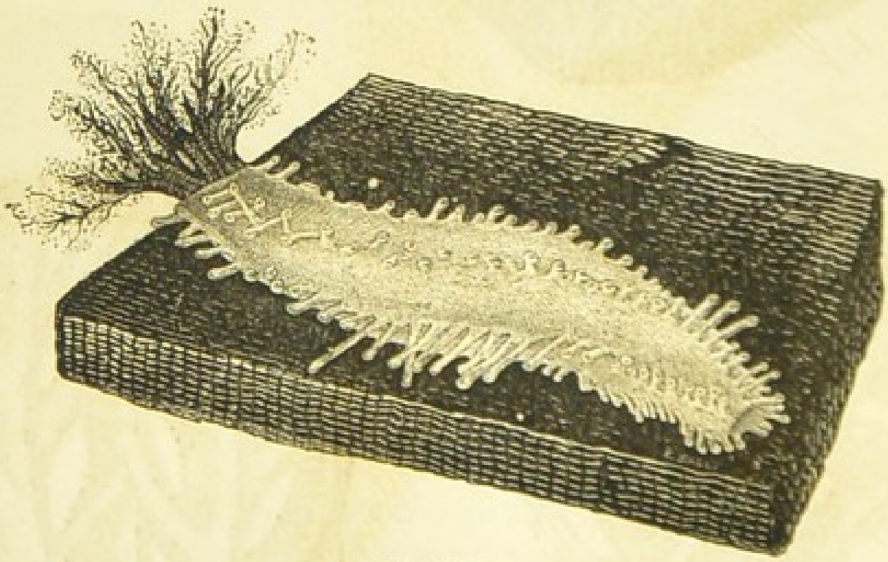


Fig. 229.
HOLOTHURIA.

times supported by a sort of solid skeleton, fig. 229, the internal

*. D'Orbigny.

structure of which is very complicated. They are formed to

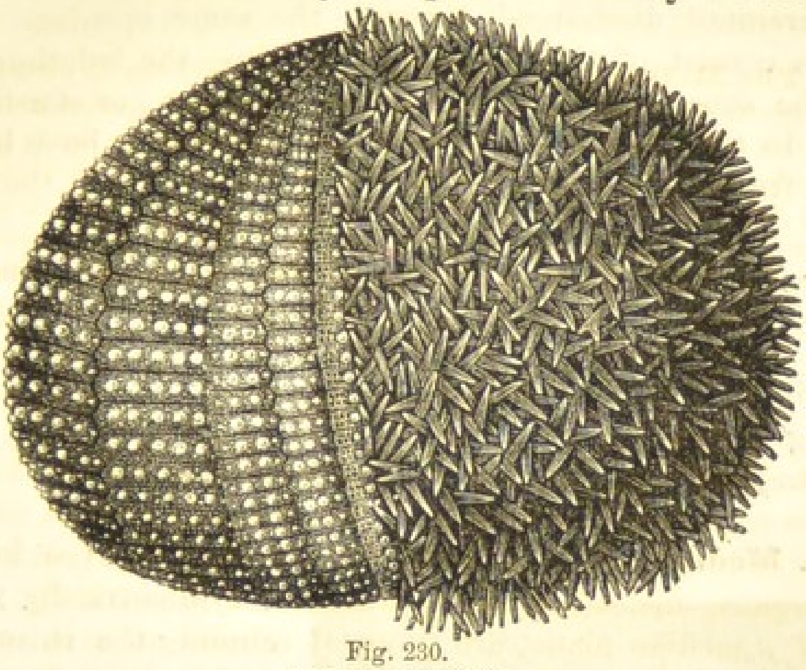


Fig. 230.
THE SEA-URCHIN.

creep at the bottom of water ; most of them, like the sea-

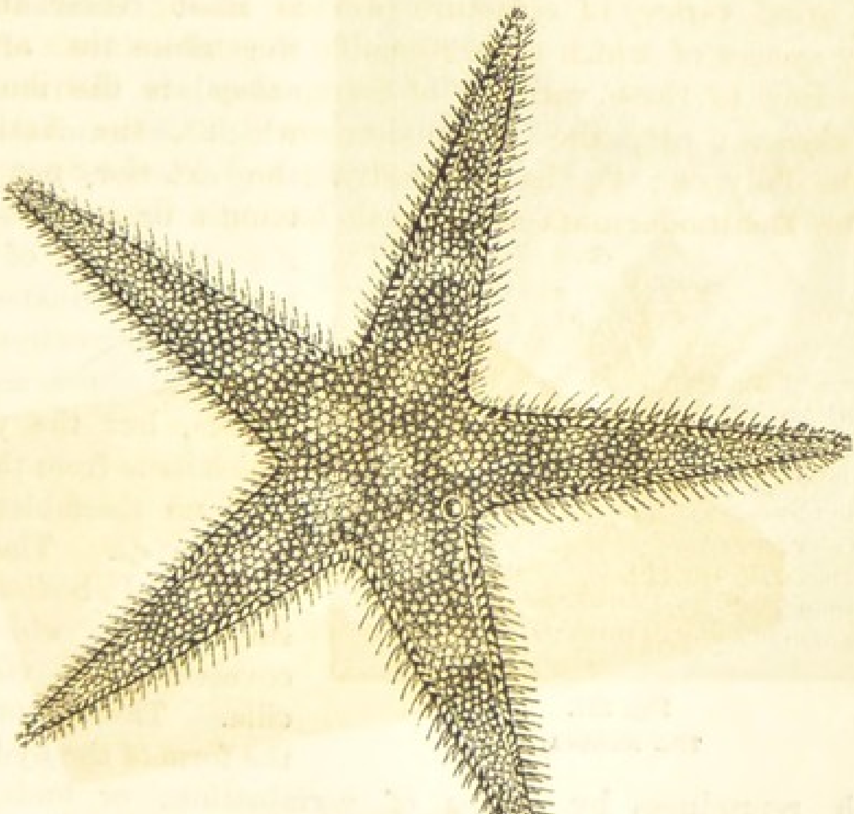


Fig. 231.
THE STAR-FISH.

urchin, fig. 230, have a digestive tube, open at both ends ;

but with some, as the star-fish, fig. 231, the food is received, and the excrement discharged, through the same opening. These animals consist of three principal groups—the holothuria, fig. 229, the sea-urchin, fig. 230, and the asterias, or star-fish, fig. 231. In the figure of the sea-urchin, the spines have been removed from the left side to display the structure of the shell.

295. **The Acalepha, or Sea-nettles,** are animals having a body of gelatinous consistency, organised for swimming in the sea. The organisation is reduced to the most simple form, consisting of little more than a stomach, having only one opening for reception and discharge, and having canals ramifying to different parts of the body.

296. **Medusa.**—The family of this class which is best known is the Medusa, fig. 232, including the rhizostomes, which abound on all the coasts of Europe. What is most remarkable in the structure of this animal is the stomach, which communicates with the exterior, not by a mouth or anus, but by a great number of small tubes, terminated by pores at their extremities.

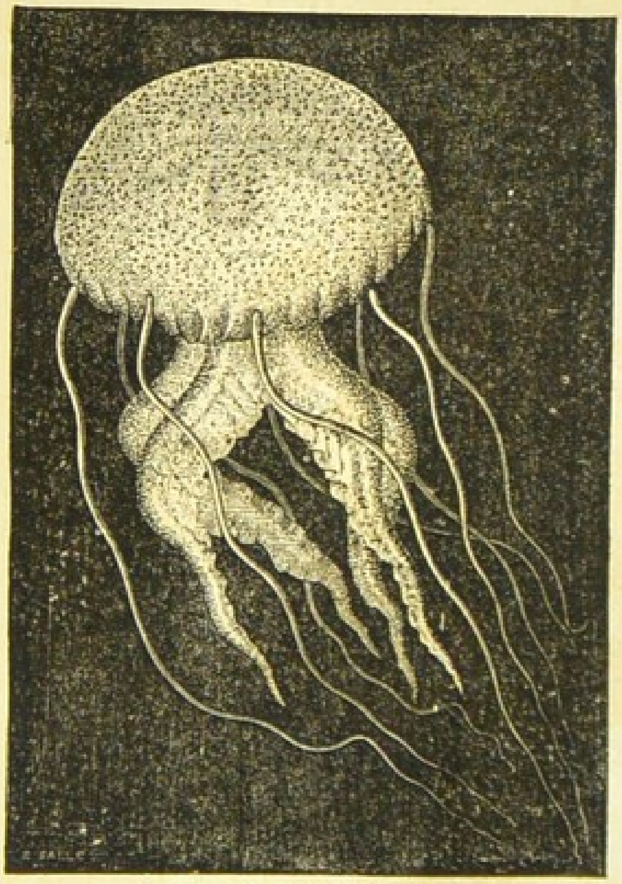


Fig. 232.
THE MEDUSA.

The Medusæ are oviparous, but the young, which issue from the egg, bear no resemblance to the parent. They are small oval bodies, the surface of which is covered with vibratile cilia. These soon take the form of the hydroida, which reproduces by means of germination, or buds, and the multitude of animals thus produced detaching themselves successively, assume ultimately the form of the Medusa.

297. **Coral Animals, or Polypes,** have bodies cylindrical,

soft, with a mouth at the extremity surrounded by tentacula, which serves equally for the reception of food and the ejection of excrement. It leads into a great cavity which occupies the entire body, and which contains the ovaries attached to its sides, and is continued upwards to the tentacula. The inferior part is so constituted as to adhere to bodies, fixed upon which the animal is destined to live. The skin is for the most part hardened, so as to form a horny or calcareous envelope analogous to the cells of the Bryozoares already described.

These Polypes resemble the Molluscoids also in their mode of propagation, being multiplied as well by germination as by eggs, so that successive generations remain fixed one upon another, forming masses more or less considerable, which include multitudes of individuals of the same race, and having as it were, a common vitality.

The part of the tegumentary covering of these animals which is hardened forms sometimes tubes, and sometimes a

Fig. 233.
POLYPES OF THE GENUS ASTEROIDES.

species of cells, with which every one is rendered familiar by corals. These were long regarded as merely the habitation of the animal.

298. **Coral Reefs and Islands.**—Sometimes each polyp posesses a distinct tube, or cell ; but, generally, it is common to a mass of the animals. It is thus that polypes, the bodies of which individually, do not exceed some inches in length, raise

coral reefs and islands in the tropical seas. Under circumstances favourable to their development, these animals completely cover chains of rocks and extensive banks, so as to produce masses of constantly increasing magnitude by the incessant accession of new bodies as the animals multiply. The solid remains of such a colony continue after these frail races have perished successively, and serve as the foundation upon which succeeding tribes erect new structures, until at length the accumulation rises above the surface of the ocean, and forms an island. The island thus formed, soon becomes the theatre of phenomena of another order. Decaying animal and vegetable matter, resting on it, form a soil. Vegetable seeds carried by the winds and the waves germinate there, and speedily cover the surface with a rich vegetation, until at length these vast catacombs of almost microscopic zoophytes become habitable islands. In the Pacific, numerous islands thus produced are found. In general they seem to have been raised upon the craters of extinct volcanoes, since they have almost invariably a circular

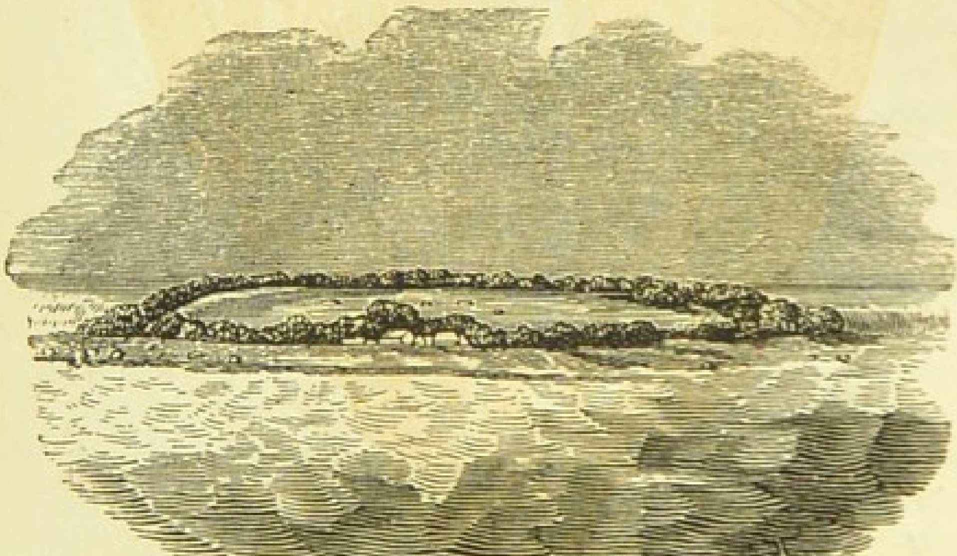


Fig. 234.
CORAL ISLAND IN THE PACIFIC.

form, and present in the centre a lake communicating by a channel with the surrounding ocean. Some of these island-lakes are thirty miles in diameter (fig. 234).

299. **Infusoria** are microscopic animalcules developed in countless numbers by decaying organic matter, immersed in water. Until recently, the wheel-animal has been erroneously

classed with these. Their bodies are round, or elongated,

Fig. 235.
PENTACRINUS FASCICULOSUS.

covered with minute cilia, and show in the interior many small

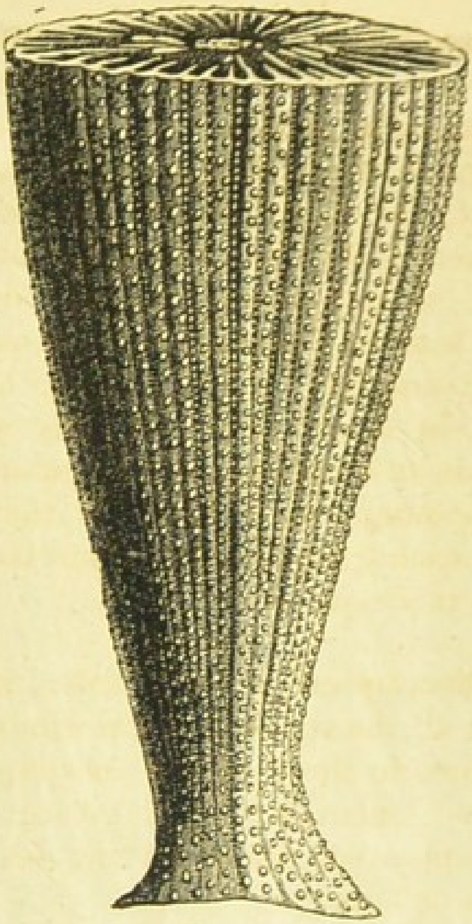
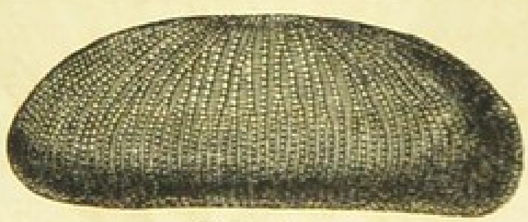
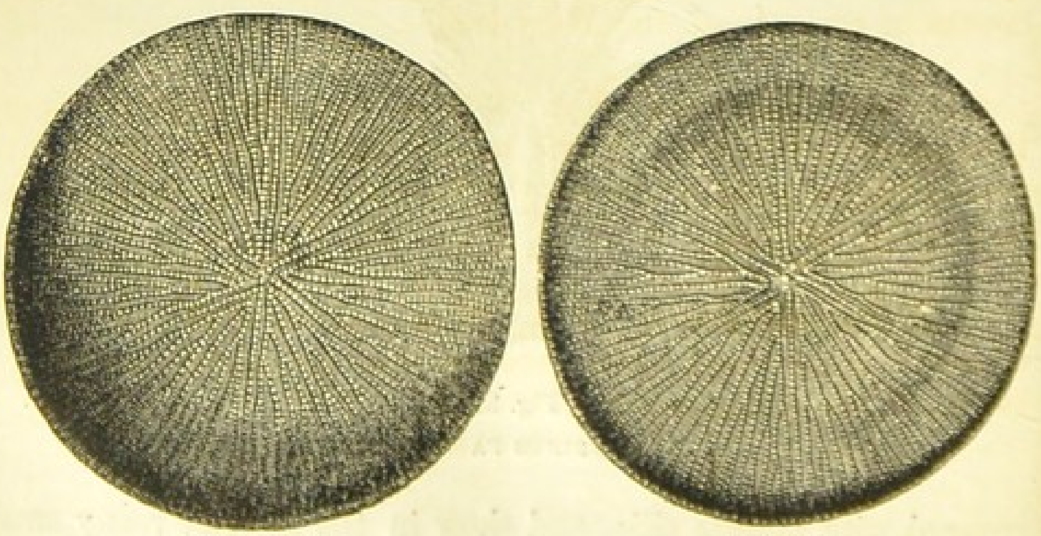


Fig. 236.
CYATHINA BOWERBANKII.



Side view.
Fig. 237.
ANABACIA ORBULITES.



Upper surface. Lower surface.

* D'Orbigny.

cavities which have the properties of stomachs. Sometimes these communicate with a canal having two open extremities, but often no communication with the exterior is apparent. Naturalists are not agreed as to their mode of propagation. It was formerly thought, and is still believed by some, that they can be produced directly, by the decomposition of vegetable and animal matter: this, however, is very doubtful, and it is certain that, at least in the case of some species, they are propagated one by another. It is certain, however, that their reproduction is in accordance with the simplicity of their structure; since in most cases, these singular creatures are multiplied by the spontaneous division of their bodies, into two or more parts, each part becoming an individual similar to that from which it is separated.

300. **Fossil Zoophytes** of every order are found in countless numbers, in all the strata from the silurian upwards. Their forms are analogous to those of the existing species, although multitudes of the genera, and still greater multitudes of the species, have disappeared, many having become extinct in the earliest geological epochs.

Of the vast numbers of specimens of every order supplied by the researches of paleontologists, we must here limit ourselves to a few.

301. **The Pentacrinus Fasciculosus.**—Fig. 235 is a specimen of the genus of the radiated Zoophytes, of which thirty-seven fossil species are known. They first appear in the upper strata of the trias, and are most numerous in the Oxford clay of the oolite group. The living species inhabit great depths in the seas of the West Indies.

302. **The Cyathina.**—Fig. 236 is a specimen of the fixed Polypes, of which five fossil species are known. They first appear in the upper strata of the cretaceous group, and increase in number upwards.

303. **The Anabacia.**—Fig. 237 is a genus of the free polyp, of which three fossil species are found in the middle and lower strata of the oolite group.

CHAPTER V.

THE NERVOUS SYSTEM.

304. THE nervous system is the link between mind and matter. In all animals it connects instinct and intelligence with the organism, in man especially the soul with the body. There is no part of the corporeal structure whose empire is so general and extensive. So essential is its supremacy that its suppression involves that of life itself. It is the recipient of impressions from without, and the messenger of dictates from within, and constitutes therefore the means by which the individual is placed in communication with the external world. Its development is the unerring measure of elevation in the scale of intelligence, and it is accordingly the organ by which the superiority of the human race over all the kingdoms of nature is manifested in the most striking manner.

The control of the nervous system, not limited to those powers which have relation to sense and will, extends equally to the functions whose exercise is independent of consciousness, which are even more essential than sensation itself to the conservation of vitality. Thus its dominion over circulation and nutrition is as absolute as over feeling and volition. While it executes the commands of the will in general, it reacts on the will in all special cases where the exigencies of the organism are imperious, and reacts moreover with an energy always proportionate to the necessities of the case. It is thus that the pain which it causes to be felt is at once the notice of local injury or disease, and the stimulus to supply and redress organic want and derangement.

305. In man and all animals of analogous structure, the nervous apparatus consists of two parts which, though not altogether independent of each other, are so distinct in their functions that it is convenient for the purposes of exposition to explain them under different heads. The first is denominated the *cerebro-spinal* and the second the *ganglionic system* or *great sympathetic nerve*. The former presides over the functions of sensation and volition, the latter over those of nutrition and circulation.

306. Each system consists of central and circumferential parts; central, from which the nervous influence diverges to the circumferential, or circumferential, from which it converges to the central.

The central parts consist of masses, more or less considerable, of nervous matter collected in certain regions of the organism, the substance and form of which varies from point to point. The circumferential or radiating parts consist of innumerable cords, called *nerves*, issuing in trunks from the central parts and diverging into innumerable ramifications, which becoming more minute as their number increases, are spread over all the organs of the body.

307. These two systems have been sometimes denominated, from their respective functions, the *nervous system of animal life* and the *nervous system of organic life*.

THE CEREBRO-SPINAL SYSTEM.

308. The central part of this system is a soft mass of whitish and greyish matter, differently disposed in different parts, in the cavities of the skull and the vertebral canal, and throwing out trunks through the numerous foramina in the bony walls of these. This mass is called from its position in the skull and spine, the *cerebro-spinal axis*.

309. That part which occupies the skull is called the *encephalon*, from the Greek word εγκεφαλος (enkephalos) *in the head*.

That part which is deposited in the vertebral canal is called the *spinal cord* or *spinal marrow*.

The encephalon consists of several distinct parts, differing in form, substance, and functions, the principal of which are the *cerebrum*, the *cerebellum*, and the *medulla oblongata*.

310. The nervous matter composing the cerebro-spinal axis, besides the protection it receives from the bony casing in which it is deposited, is enveloped within this casing by three membranous coats, placed one within the other, called the *dura mater*, the *arachnoid*, and the *pia mater*.

311. **Dura Mater.**—The dura mater, which is the external coat, is a strong, thick, fibrous membrane. It adheres in many places to the inner surface of the cranial bones and descends in folds into the fissures which separate the large divisions of the cerebral matter, thus forming between them

a partition which prevents their displacement, and protects them from any undue mutual pressure which might attend the ever varying position of the body and its members.

312. **Arachnoid.**—The arachnoid (ἀραχνη, cobweb) membrane, so called from its resemblance to a spider's web in its texture, is the second coating. Part of it is in immediate contact with and, inseparable from the dura mater, which has so far the character of a fibro-serous membrane. A space intervenes between the arachnoid and the pia mater, filled with a liquid called the *cerebro-spinal fluid.*

This fluid, submitted to analysis by M. Lassaigne, was found to consist of $98\frac{1}{2}$ per cent. of water combined with 0·8 per cent. of common salt and chloride of potassium, with very small proportions of osmazome, albumen, phosphate of lime, and carbonate of soda.

Physiologists are not agreed as to its origin. According to Cruveilhier it is secreted by the arachnoid, and according to Haller, Magendie, and Longet, by the pia mater. Its total quantity weighs about 2·12 ounces, but varies according to age and sanitary condition.

Its use is to fill the vacant spaces which exist between the different parts of the cerebral matter, such as the anfractuosities and fissures which divide the convolutions of the brain, and also the space which intervenes between the dura mater and the nervous centres. It may therefore be considered as discharging a function similar to that of a lubricant, preventing the injurious contact, friction, and pressure which might attend the changes of position consequent upon the flexibility of the vertebral column, and the mobility of the head.

313. **Pia Mater.**—The pia mater, in immediate contact with the nervous matter, is a cellular web, having but little consistency, in which an infinity of minute and tortuous blood-vessels are ramified and interlaced in a thousand different directions. One of the uses of this envelope is supposed to be to moderate the force with which the blood is propelled through the delicate cerebral structure. It would seem to act after the manner of a breakwater.

314. A theoretical illustration of the general form and disposition of the cerebro-spinal system is given in fig. 238.

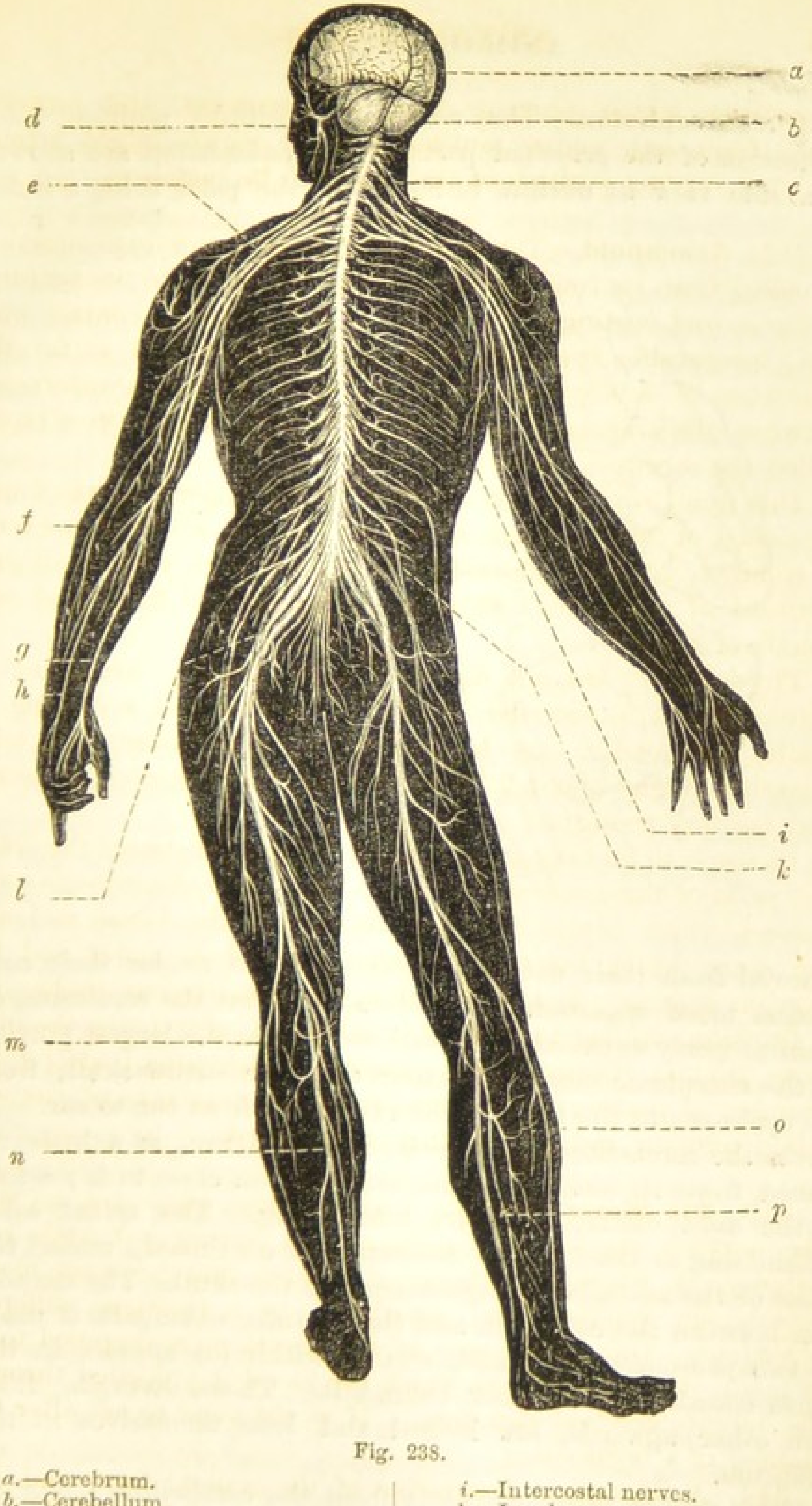


Fig. 238.

a.—Cerebrum.
b.—Cerebellum.
c.—Spinal cord.
d.—Facial nerve.
e.—Brachial nerves.
f.—Median nerve.
g.—Ulnar nerve.
h.—Internal cutaneous nerve.
i.—Intercostal nerves.
k.—Lumbar nerves.
l.—Sciatic plexus.
m.—External peroneal.
n.—Tibial nerves.
o.—External peroneal nerve.
p.—External saphene.

315. **Encephalon.**—The relative magnitude, position, and connection of the principal parts of the encephalon are shown by a side view in outline in fig. 239; the parts being a little

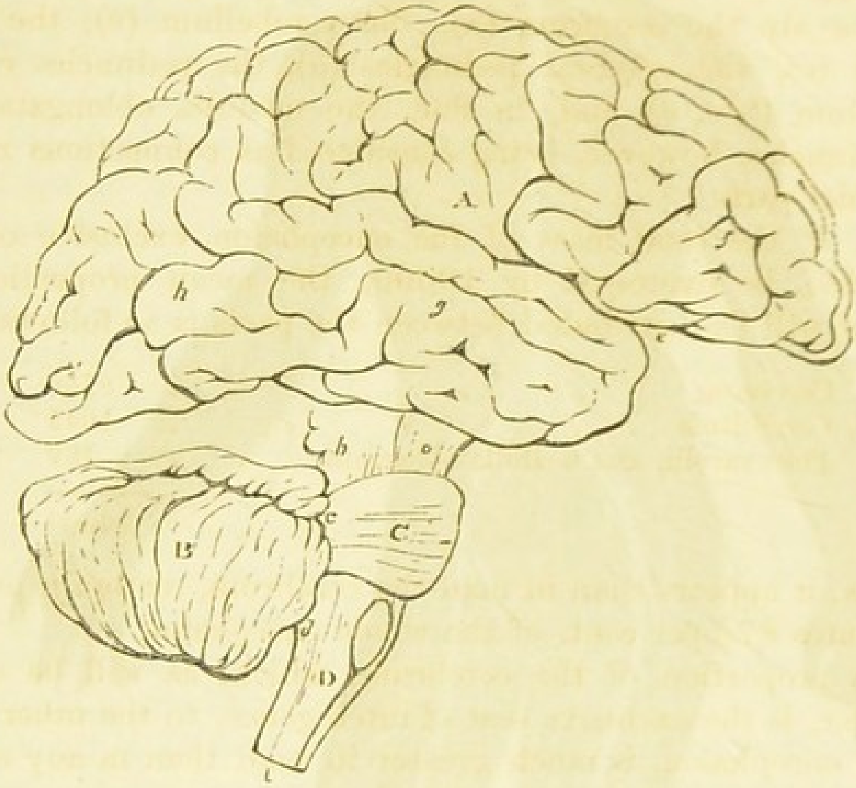


Fig. 239.

removed from their natural juxtaposition to render their connection more apparent. It will be seen that the cerebrum, or brain properly so called (A), constitutes by far the largest portion of the encephalic mass, extending over the entire skull, from the eyebrows to the back of the skull, and from ear to ear. It covers the cerebellum (B), which, in the figure, is a little removed from it, but in the natural position close to it; a fold of the dura mater, however, intervening. The spinal cord, terminating at the foramen magnum, is continued, under the name of the medulla oblongata (D), into the skull. The connection between the cerebrum and the medulla oblongata is made by two *peduncles*, or stalks, one of which (*a*) appears in the figure concealing the other behind it. These, diverging from each other upwards, are lodged and lose themselves in the cerebrum.

Three pair of peduncles issue from the cerebellum; one (*b*) directed upwards to the cerebrum, another (*d*) downwards to the medulla oblongata, and the third (*c*) forwards, being connected by a band of cerebral matter (C) continuous with

them passing in front of the peduncles, and called the *pons Varolii* (c),* being as it were a bridge passing over the junction of the peduncles and the medulla oblongata.

It appears, therefore, that the principal parts of the encephalon are the cerebrum (A), the cerebellum (B), the pons Varolii (C), the cerebral peduncles (*a*), the peduncles of the cerebellum (*b*, *c*, *d*), and, in fine, the medulla oblongata (D); the peduncles, however, being considered as connections rather than chief parts.

316. If the total mass of the encephalon, exclusive of the peduncles, be expressed by 10000, the mean proportion in which it will be distributed between the parts is as follows :—

Cerebrum	8756
Cerebellum	1045
Pons varolii, and medulla oblongata . .	199
	10000

Thus, it appears than in man the cerebrum, or brain proper, constitutes $87\frac{1}{2}$ per cent. of the whole encephalon.

This proportion of the cerebrum, which, as will be shown hereafter, is the exclusive seat of intelligence, to the other parts of the encephalon, is much greater in man than in any of the inferior species.

317. The absolute mean weight of the brain, separated from the subordinate parts, according to the observations of Cruveilhier, is 44·1 ounces, the limits of its variation being, in the adult, 53 ounces and 35 ounces. M. Parchappe found nearly the same average weight of the cerebrum in the case of twenty-nine adult men.

The absolute weight of the brain, irrespective of the total weight of the body, is greater in man than in the immense majority of animals. Three species only—the dolphin, the elephant, and the whale—present exceptions to this. The average weight of the brain of the dolphin is found to be about $63\frac{1}{2}$ ounces, and that of the elephant and whale about 53 ounces. But, since the cerebellum and other subordinate parts constitute the sixth part of the whole weight, it follows that the brain properly so called of the dolphin weighs only 53 ounces, and that of the elephant and whale 44. The difference, therefore, between the gross weight of those cerebral organs and that of man is inconsiderable, while the comparison

* So called from Constanzio Varoli, a celebrated Bolognese anatomist of the sixteenth century.

of the weight and volume of the brain with that of the whole body gives to man an immense superiority. For while the weight of the human brain amounts to the 36th part of that of the whole body, that of the dolphin amounts to only the 100th part; that of the elephant to the 500th part; and that of the whale to a much smaller fraction.

In the ox and the horse the mean weight of the brain is only 21·1 ounces, being less than half the mean weight of the human brain, while the total weight of the bodies of these animals is six or eight times that of the human body.

318. Numerous observations have been made with a view to determine the proportion which the weight of the brain in different classes of animals bears to the total weight of the body. Although in such observations there are accidental differences and errors in individual cases, these are effaced in taking the mean results of sufficiently numerous experiments. In pursuing this course, M. Leuret has obtained the following results for the several classes of vertebrated animals, ascending from fishes to man. Supposing the total weight of the body to be expressed by 10000, the following are the average weights of the brain :—

Fishes	1·8
Reptiles	7·6
Birds	47·2
Mammifers	53·8
Man	277·8

These results demonstrate that the development of the cerebral organ is more and more considerable in ascending in the scale of intelligence.

319. This proportion which the cerebral development bears to the total weight in comparing class with class, is not so evident when we come to compare together varieties or individuals. Although it has been maintained by some physiologists that the cerebral development in man varies in proportion to the stature or weight, other and higher authorities hold with Bichat that it is completely independent of the stature.

Numerous observations have been made with a view to determine the comparative cerebral development in the different races, according to which naturalists have classed the human species. The general result of such researches has been favourable to the conclusion that the cerebral development is greatest in the Caucasian race, which includes the Europeans, and least in the negroes. Soemmerring found, by measurement of

the skulls of the different races, that all the dimensions were less in the negro than in the European. Tiedemann, adopting a different method of determining the capacity of the skull, first weighed the empty skulls, and afterwards weighed them with their cavities filled with millet seeds, and took the difference of weights as a measure of their different capacities. By this method, applied to forty-one negroes and seventy-one Caucasian skulls, it appeared that there was no perceptible difference of capacity.

But it must be observed that these methods determine, not the relative capacities of the cerebrum, properly so called, which is the exclusive seat of intelligence, but the total volume of the cerebral mass. Professor Bérard accordingly measured, with great accuracy, the various dimensions of numerous well-authenticated negro skulls, which had been placed at his disposal, and found, in accordance with the results of Tiedemann's observations, that the total volume of the cerebral cavities was not less than their average capacity in European skulls, but that the distribution of the space was different, a larger proportion being assigned to the posterior and inferior parts of the skull in the negro, than in the European.

It would therefore follow, from these results, that the cerebrum, properly so called, is proportionally more developed than the subordinate parts which occupy the hinder and lower cavities of the skull, in the European than in the African race.

320. By a comparison of the cerebral organs of woman with man, M. Parchappe found that the weight of the male brain is, on an average, nine per cent. greater than that of the female. It might be maintained that this inferiority of development in the female brain is merely a consequence of the inferior dimensions and weight of the female body; and some physiologists, including Meckel, have even maintained that the female brain, relatively to the total dimensions of the body, is greater than the male. Against this, M. Parchappe maintains that the whole encephalic mass, which is less in woman by one-eleventh than in man, is not sensibly greater, relatively to the whole mass of the body, and therefore that its absolute inferiority is not compensated by its relative superiority.

321. Of all questions connected with cerebral development, the most interesting by far are those which involve its relation to the comparative intellectual powers of individuals, but there are none concerning which the number of well established data are more insufficient. It cannot be doubted that many prominent

cases are recorded of extraordinary cerebral development in remarkable men, though such cases are not always satisfactorily authenticated. Five of the most remarkable are the following :—

	oz.
Cromwell	100
Byron	79
Cuvier	$64\frac{1}{2}$
Abercrombie, M.D.	63
Dupuytren	$50\frac{2}{3}$

Of the above cases, the first and second are probably exaggerated—the first certainly so ; the others have been well ascertained ; but such instances are not sufficiently numerous to supply a safe basis for any general conclusion. The most direct and certain means of deciding, by immediate observation and experiment, the relation between cerebral development and intellectual phenomena, would be the comparison of the mean weight of the brains of idiots with those of persons of sound mind. M. Lélut has, accordingly, made numerous observations with this view, the general result of which is, that the mean weight of the encephalon is less in idiots than in individuals of sane mind, and that this disproportion is much more marked in the cerebrum than in the subordinate parts.

322. **Cerebrum, or Brain.**—The cerebrum is divided, at its superior surface, by a fissure extending along the middle of the head, in the median plane, and occupying a position coinciding with the crest of a helmet. This channel, which commences at the lower part of the forehead, and terminates a little above the nape of the neck, is called the *longitudinal fissure*. The two parts into which it divides the cerebrum, which are perfectly identical and symmetrical, are denominated, without much propriety of language, *hemispheres*. They are, of course, convex without, and concave within, being moulded according to the form of the sides of the skull.

323. The cerebrum consists of a multitude of large vermiform convolutions, and has the appearance of coils of thick vermicelli gathered up confusedly together. The longitudinal fissure passes quite through to the base of the cerebrum, from before to behind, completely separating the two hemispheres ; but near the middle, at a certain depth, it is traversed at right angles by a mass of white substance, called the *corpus callosum*.

This general description will be more clearly comprehended by reference

to figs. 239 and 240. Fig. 240 represents a vertical longitudinal section of the encephalon, made in the direction of the longitudinal fissure, showing in their natural position the parts, which in fig. 239 are represented displaced, together with other parts omitted in the latter figure. Immediately under the middle of the cerebrum is seen, in section, the corpus callosum (240, [26]), the upper surface of which is convex, and the under concave, and nearly parallel to it. The cerebellum lying beneath the posterior part of the cerebrum, is shown in section, at 240,[4]; the medulla oblongata, at 240,[1], the pons Varolii, at 240,[2]; and the cerebral peduncles, at 240,[3].

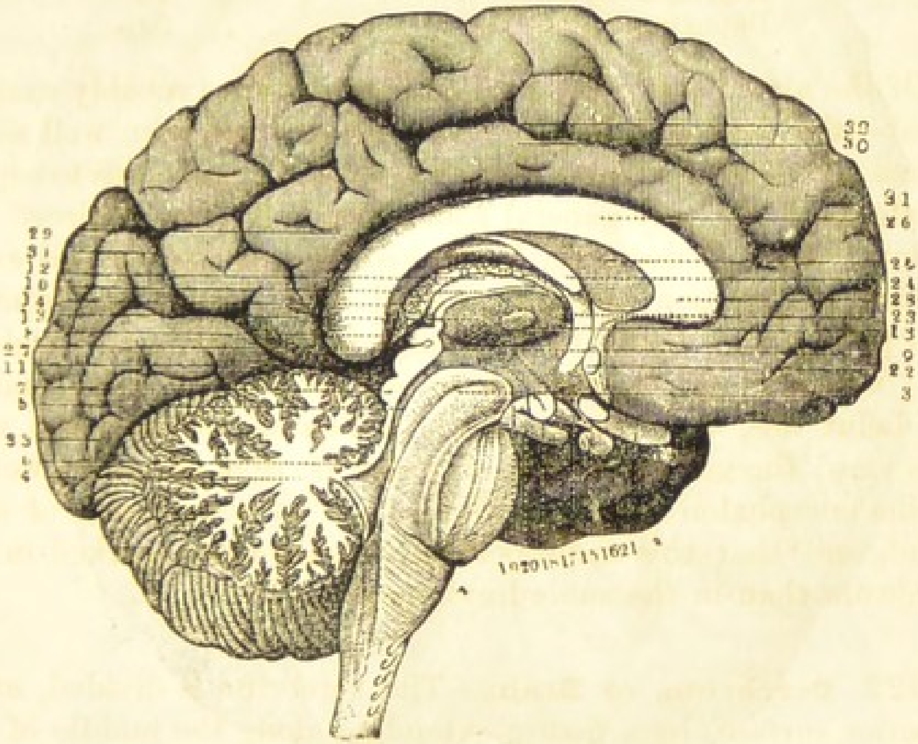


Fig. 240.*

VERTICAL SECTION OF THE ENCEPHALON THROUGH THE GREAT LONGITUDINAL FISSURE.

The cerebrum, divested of its membranous coverings, and viewed from above, presents the appearance of a continuous mass of vermiform convolutions, divided along the middle by the longitudinal fissure, and extending before and behind to the forehead and the neck, and at the sides to the ears. If the middle part of the convolutions be removed, the surface of the corpus callosum will be revealed, and will present the appearance shown in fig. 241,[1]. It is traversed, as will be seen, by a longitudinal groove (241,[2]), and parallel to this, at either side, by elevated ridges (241, [4]). In its posterior part, it is formed into a slightly obtuse angle, within which are seen the edges of the superior surface of the two hemispheres of the cerebellum (241,[13]), united by the vermiform process. The cerebral convolutions appear around the external border of the corpus callosum.

324. The inferior or concave surface of the corpus callosum forms the roof of a cavity of curious and complicated structure.

* From the original of Hirschfeld and Leveillé.

The floor of this cavity consists of certain structures and projections, to which anatomists have given more or less fanciful

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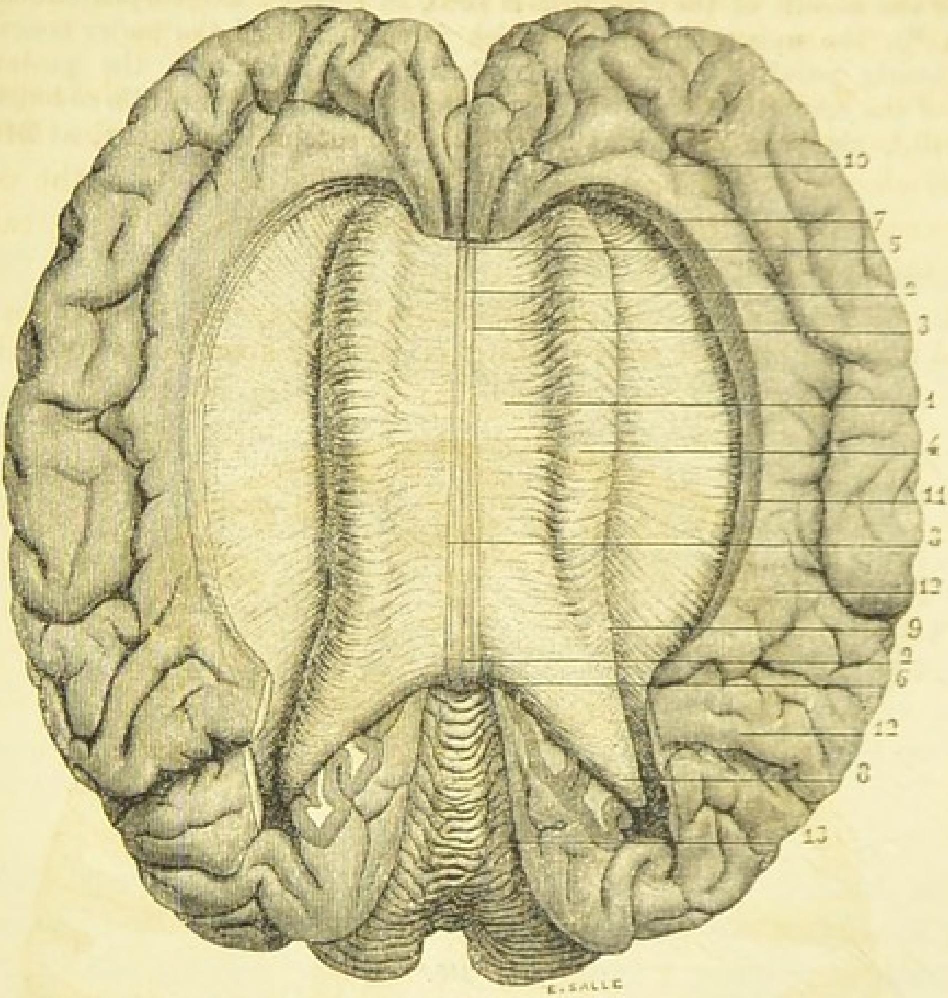

BACK.

Fig. 241.*

THE CEREBRUM VIEWED FROM ABOVE, THE MIDDLE CONVOLUTIONS BEING REMOVED SO AS TO SHOW THE SUPERIOR SURFACE OF THE CORPUS CALLOSUM.

names. These parts, taking them in the order of their position from the front towards the back of the head, are :—

1. Corpus striatum.
2. Tænia semicircularis.
3. Thalamus opticus (240,[12],[13]).
4. Choroid plexus.
5. Corpus fimbriatum.
6. Fornix (240,[24]).

Some of these are shown in section, in fig. 240.

325. **Septum Lucidum.**—Of the two compartments into which the cerebral cavity is divided by this complex floor, the upper is again divided into two by a vertical longitudinal partition, coinciding in position with the median plane, called the *septum lucidum*, two Latin words, signifying "a transparent

* Foville.

partition." From its position, the septum lucidum coincides with the plane of the section shown in fig. 240, and is therefore represented by the space 240, [25], included between the lower surface of the corpus callosum (240, [26]) and the general flooring which divides the entire cerebral cavity horizontally.

326. **Ventricles.**—The two chambers into which the septum lucidum divides the upper compartment are called the *lateral ventricles*, and distinguished as the right and left ; the compartment below the flooring, not similarly divided, being called the *third ventricle.*

To convey some idea of the complicated flooring which separates the third from the first and second ventricles, we have given in fig. 242 a hori-

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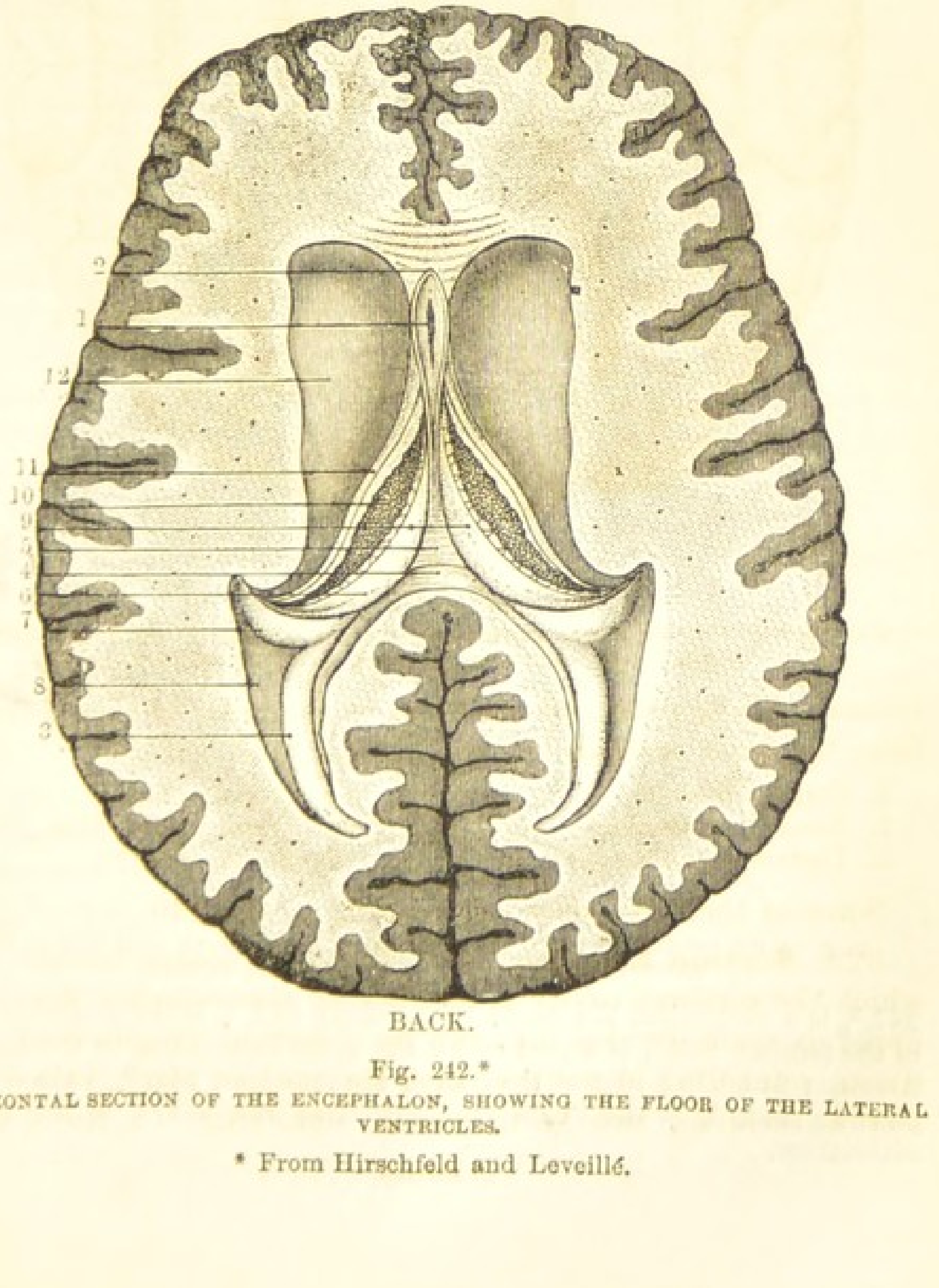

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Fig. 242.*

HORIZONTAL SECTION OF THE ENCEPHALON, SHOWING THE FLOOR OF THE LATERAL VENTRICLES.

* From Hirschfeld and Leveillé.

zontal section of the encephalon, made at the level of this flooring, where 242,^{12}, is the corpus striatum; 242,^{2}, the extremity of the section of the septum lucidum, which, as will be seen, is composed of a double lamina separated to the right and to the left, so as to enclose a spindle-shaped space, in the middle of which is a small cavity, (242,^{1}), called the fourth ventricle; 242,^{5}, is the fornix; 242,^{4}, is the section of the flange, or border of the corpus callosum, which there descends to the floor of the ventricles;

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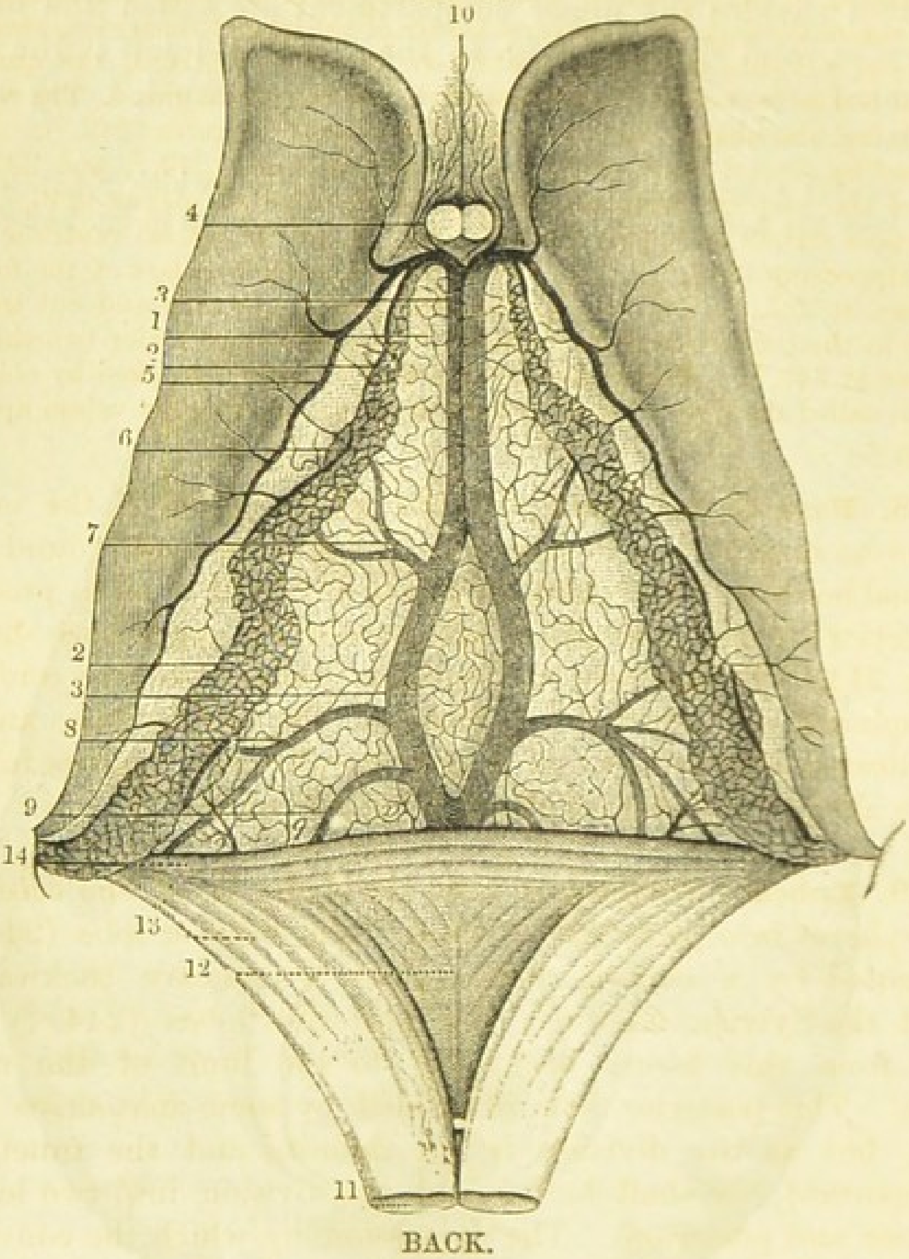

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Fig. 243.*

THE VELUM INTERPOSITUM, LYING BETWEEN THE FORNIX AND THE PARTS BENEATH, SHOWN BY RAISING UP THE FORNIX.

242,^{3}, is a part called the small hippocamp; 242,^{6}, is the posterior pillar of the fornix; 242,^{7}, is a part called the great hippocamp, or the horn of Ammon; 242,^{8}, is a part of the floor of the ventricle; 242,^{10}, is the choroid plexus; 242,^{11}, is the tænia semicircularis; and 242,^{9}, is the corpus fimbriatum.

* From Sappey.

327. **Velum interpositum.**—A remarkable structure, called the *velum interpositum*, or choroid web, is interposed between the fornix and inferior parts. It is shown, with the adjacent parts, in fig. 243.

This web (243, [1]), which is highly vascular, connects the two choroid plexuses, (243, [2]), and as well as the latter, is merely a production, or continuation, of the pia mater, which, passing from the outer surfaces of the brain, enters through the transverse fissure of the lateral ventricles, beneath the corpus callosum and fornix, and above the optic thalami, the quadrigeminal bodies (to be described presently), and the pineal gland. The velum has a triangular shape, its sides being the choroid plexuses (243, [2]). It is traversed by several veins, such as the veins of Galen (243, [3], and 243, [5]), veins of the corpora fimbriata (243, [6]), of the choroid plexus (243, [7],) of the corpora striata and optic thalami, (243, [8]), of the lateral ventricle and great hippocamp (243, [9]). The section of the interior pillars of the fornix is shown at 243, [11], and the fornix itself turned upwards and cut transversely at the connection of its anterior third, with its posterior two-thirds, is shown at 243, [11]. The triangular depression, 243, [12], marked by oblique striæ, is called the lyre. Small arteries running through the velum appear at *a*, *b*, *c*.

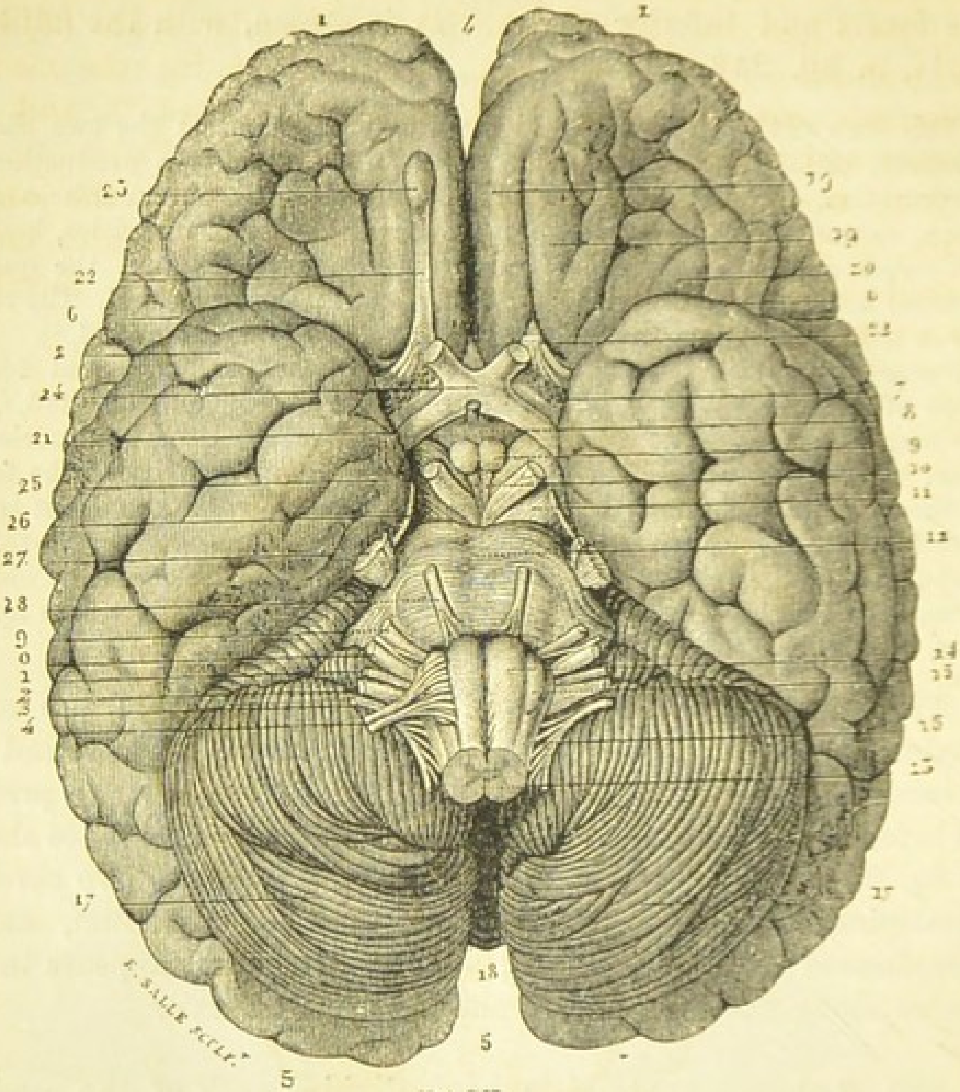
328. **Base of the brain.**—If the entire mass of the encephalon be imagined to be removed by a section made round the external borders of the skull, and to be inverted so as to present its inferior surface upwards, it will present the appearance shown in fig. 244. In this case, the posterior parts of the two cerebral hemispheres are covered by those of the cerebellum, and a complicated structure, to be presently described, appears in the centre along the direction of the longitudinal axis.

329. **Lobes.**—Anatomists have divided each of the cerebral hemispheres into parts called *lobes*. The anterior lobe (244, [1]) is limited by a curved fissure (244, [6]), concave backwards, called the Sylvian fissure. The posterior lobes (244, [3]) extend from this fissure backwards to the limit of the cerebrum. This posterior lobe is divided by some anatomists into two; but as the division is not definite and the functions unimportant, we shall here adopt the division into two lobes, anterior and posterior. The depression by which the convolutions are separated, called anfractuosities by foreign and sulci or grooves by English anatomists, have generally received special names, according to their positions relatively to other principal parts of the organ; but it will not be necessary here to reproduce the nomenclature.

330. The substance composing the cerebrum consists of white matter internally, coated externally by a thin layer of

greyish matter, which has been called the cortical matter, from

FRONT.



BACK.

Fig. 244.*

INFERIOR SURFACE OF THE ENCEPHALON, DIVESTED OF ITS MEMBRANOUS COATING.

its relation to the white matter being analogous to that of the bark of a tree to the wood within it.

331. **Cerebellum.**—The structure and substance of the cerebellum (244 [17]) differ from those of the cerebrum. The cerebellum is not formed into convolutions, but laminated and foliated like the leaves of a book. On making a section of the cerebellum, in the direction of the median plane, a remarkable internal structure (fig. 240 [4]) is presented, called from its peculiar appearance the *arbor vitæ*. This is produced by the extension of processes of white matter from the centre into the laminæ, which consist of grey matter.

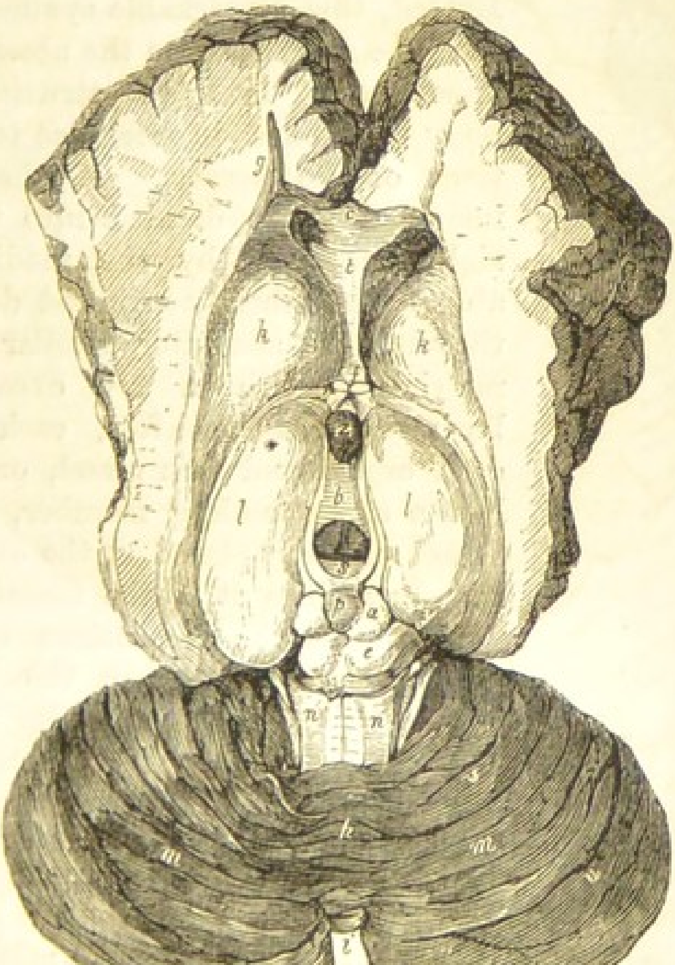
332. Besides the roots of several pairs of nerves which are

* From Hirschfeld and Leveillé.

cut off, the chief parts which are presented in the middle of the base of the brain are the pituitary body (fig. 244,[8]), the corpora albicantia (244 [9]), the interpeduncular space (244, [10]), the peduncles (244 [11]), the pons Varolii (244, [12]), the medulla oblongata cut off (244, [13]), the pyramids (244 [14]), and the olivary and restiform bodies (244, [15]), and (244, [16]).

333. **Corpora quadrigemina.** — Concealed by the central parts, in fig. 244, there are some of small magnitude, but of considerable functional importance, which we have, therefore, shown in fig. 245.

FRONT.



BACK.

245.*

This is a section of the cerebrum, made through the cavity of the middle ventricle, showing the surfaces of the corpora striata and the optic thalami. The parts marked *a e*, and the two corresponding parts on the left, are called the *corpora quadrigemina;* *c* is the corpus callosum, *f* the anterior

* Quain.

pillars of the fornix, *k k* the corpora striata, *l l* the optic thalami, *z* to *z* the middle ventricle, and *p* the pineal gland with its peduncles.

The section in fig. 245 is made deeper than that shown in fig. 242.

334. **The Nerves in general.**—From the encephalon and the spinal cord all the nerves of the cerebro-spinal axis diverge. A general theoretical view of these is shown in fig. 246. These nerves, on either side of the axis, are perfectly similar and symmetrical; for every nerve which issues from it to the right, there is a corresponding one, absolutely identical with it, and proceeding to a corresponding part of the body, on the left. Indeed, this remarkable symmetry might easily be foreseen from the necessity which arises for it, from the structure of the body considered in reference to the functions of the nerves. If the body be imagined to be divided into two parts, right and left, by the median plane, already described, continued downwards, they will be absolutely similar and symmetrical. With a few exceptions, to be mentioned hereafter, each member, each organ, and each vessel, on one side, has a corresponding member, organ, or vessel similarly placed on the other side of it. But since it is the function of the nerves to be the conductors of volition and sensation between the brain and all parts of the body, it necessarily follows that the same symmetry which prevails among the other parts of the organisation must likewise exist in the nervous system. Hence it follows that nerves exist in pairs, and in pairs they issue from the cerebro-spinal axis, as shown in fig. 246.

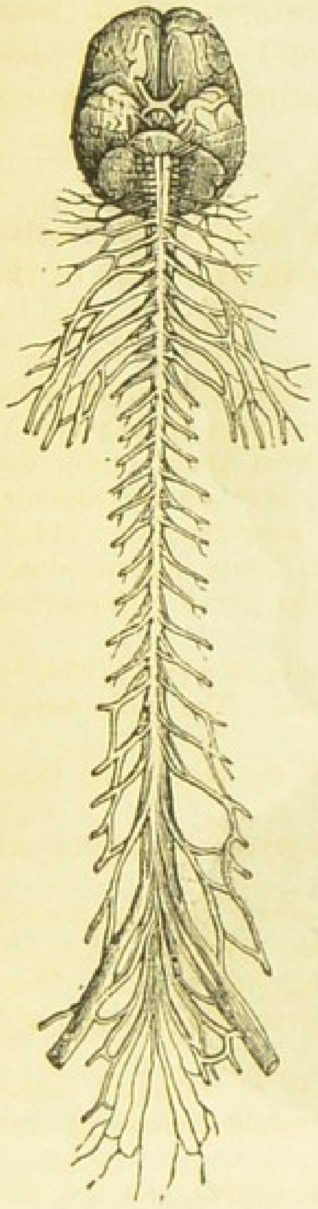


Fig. 246.*

335. Anatomists have agreed to name them according to the numerical order of their roots upon the axis, commencing from the summit of the head downwards. Thus, the first pair are those which issue from the summit of

* Edwards.

the axis, near the middle of the length of the longitudinal fissure. These are also called the *olfactory* nerves, because they go to the organ of smelling. The second pair, the next in descending order, are the optic nerves, and so on.

336. Of forty-three pairs of nerves, which thus issue from the cerebro-spinal axis, twelve have their roots in the encephalon, and issue to their respective organs through holes properly placed in the bony case of the brain. The other thirty-one issue from the intervertebral foramina, already described, in the spinal column. The twelve which issue from the encephalon are called *cranial*, and the thirty-one which issue from the vertebral column are distinguished as *spinal nerves.*

337. **Cranial Nerves.**—The points from which the twelve pairs of cranial nerves issue, are all apparent in the base of the encephalon (fig. 244).

The first pair are the *olfactory nerves* (244, [22]), which proceed to the organ of smelling. These issue from points at the inner extremities of the Sylvian fissures (244, [6]), and in proceeding from their origin forwards, are deposited in a depression or anfractuosity between two convolutions (244, [19]) The left olfactory nerve is divided near its root (244, [22]) to show its prismatic form, the angle of the prism being accommodated to the anfractuous groove in which the trunk of the nerve is deposited. 244, [23], is the bulb of the right olfactory nerve.

The second pair are the *optic nerves*, which decussate at a point (244, [24]), immediately between the roots of the olfactory nerves. The optic nerves are cut off in the figure, near their decussation.

The third pair (244, [25]) are the *motor nerves of the eye*, being those which govern the muscles which move the eyeball.

The fourth pair are the *pathetic nerves.* These nerves also govern one of the muscles of the eye.

The fifth pair (244, [27]) are called the *trifacial nerves:* they are nerves both of taste and touch, imparting sensibility, by thin divergent fibres, to the face, the fore part of the head, the eye, nose, ear, and mouth. They supply motor filaments, also, to the muscles which govern mastication, and consequently have very numerous ramifications.

The sixth pair (244, [28]) are called the *abducent* or *external motor* nerve of the eye. They act upon the external straight muscle of the orbit.

The seventh pair (244, [29]) are called the *facial nerves*, and are the motor nerves of the face, over which they spread numerous ramifications.

The eighth pair (244, [30]) are the *auditory nerves*, the ramifications of which are distributed over the internal structure of the ear. These nerves are united with the facial nerves, as shown in the figure, by a small fibre.

According to the classification of Willis, generally adopted by English anatomists, the facial and auditory nerves are taken as a single pair. In

the classification of Soemmerring, however, they are regarded as separate nerves.

The ninth pair (244, [31]) are called the *glosso-pharyngeal.* The terminal fibres of this pair, as their name implies, are spread over the tongue and pharynx.

The tenth pair (244, [32]) are called the *pneumogastric* nerves. The ramifications of this pair, which are the longest of all the cranial nerves, extend through the neck and cavity of the chest to the upper part of the abdomen. They supply nerves to the organs of voice and respiration, to the stomach and the heart.

The eleventh pair (244, [33]) are called the *spinal accessory* nerves, which receive their name from uniting with the trunk of the pneumogastric. They supply branches to the sternomastoid and trapezius muscles.

The last three pairs are classed by Willis as a single pair, and denominated the eighth.

The twelfth and last pair of cranial nerves are the *hypoglossal* (244, [34]). Their branches are spread over the fore part of the neck and the tongue. They act upon all the muscles connected with the hyoid bone, including those of the tongue, with the exception of the digastric, the mylo-hyoid, and the middle constrictor of the pharynx. They are connected also with the pneumogastric and gustatory nerves, with several of the spinal nerves, and with those of the ganglionic system.

338. **Spinal Cord.**—As already explained, the continuation of the medulla oblongata after its passage into the vertebral canal, through the foramen magnum, receives the name of spinal cord ; which, divested of its sheaths and nervous appendages, is a rod of cerebral matter, descending through the canal to about two-thirds of its entire length, and terminating in a point. Its transverse section is generally circular, but, in certain parts, slightly elliptical, the shorter axis of the ellipse being directed backwards and forwards, and the longer, right and left.

A view of the entire length of this cord seen from behind is shown in figs. 247, 248, and 249 ; fig. 247 being the upper, fig. 248 the middle, and fig. 249 the lower third of its length. The first is therefore the cervical, the second the dorsal, and the third the lumbar part. It will be observed that its transverse diameter has an enlargement in the upper and lower parts, while it is uniform in the middle part. The transverse section is elliptical at the points of enlargement, and circular elsewhere.

339. The cord is traversed longitudinally by several fissures, which show that it consists, as is demonstrated by other means, of several distinct cords combined and adhering so as to form a single one.

These two principal fissures traverse the middle of the anterior and posterior sides of the cord, the posterior fissure being shown in the figure at 1, 1, 1, 1, 1, 1. On either side of this is another fissure, marked 2, 2, which disappears about the termination of the first third of the cord.

Two lateral fissures are shown at 7, 7, 7, 7, 7, 7, and two others similar to them have corresponding positions on the anterior side of the cord. It is in these fissures (7) that the roots of the nerves which issue on each side from the cord are implanted.

340. As has been just stated, the spinal cord consists of a

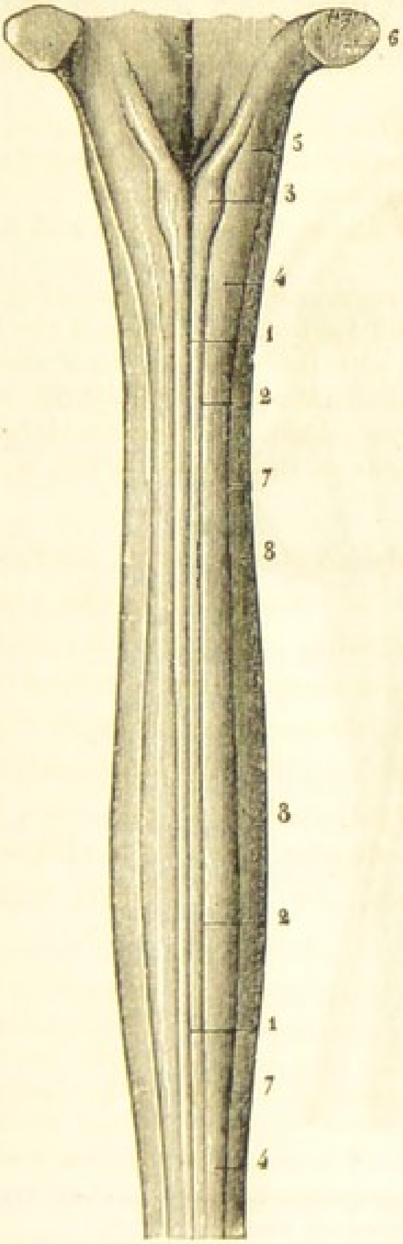


Fig. 247.*

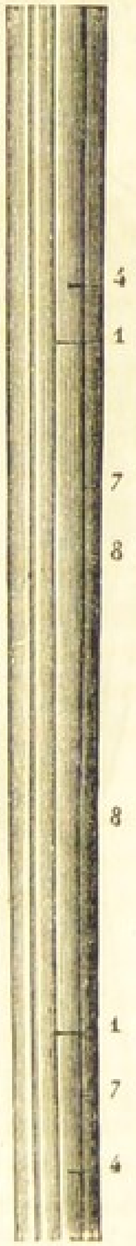


Fig. 248.*

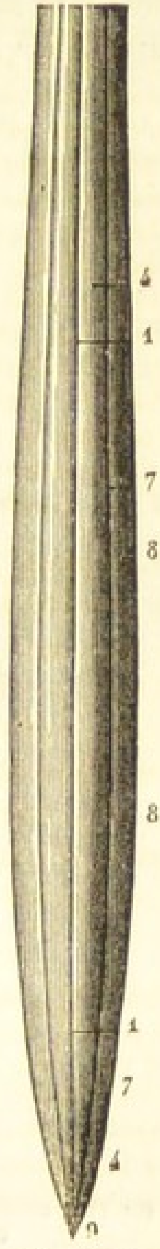


Fig. 249.*

POSTERIOR VIEW OF THE SPINAL CORD, DIVESTED OF ITS SHEATHS AND NERVOUS APPENDAGES AND CUT INTO THREE EQUAL SEGMENTS.

combination of six lesser cords, which can be separated one from another, and are shown thus separated, but cut off a little below the summit, in fig. 250 ; where it will be observed that

* From Hirschfeld and Leveillé.

the three cords of the right side intersect those of the left, before they unite in the medulla oblongata, or the pyramids, as they are called. It is only after thus intersecting and uniting that they ascend into the pons Varolii, and form the peduncles of the cerebrum, after which their constituent fibres diverge, and spread themselves out in all directions through the convolutions of the lobes of the brain.

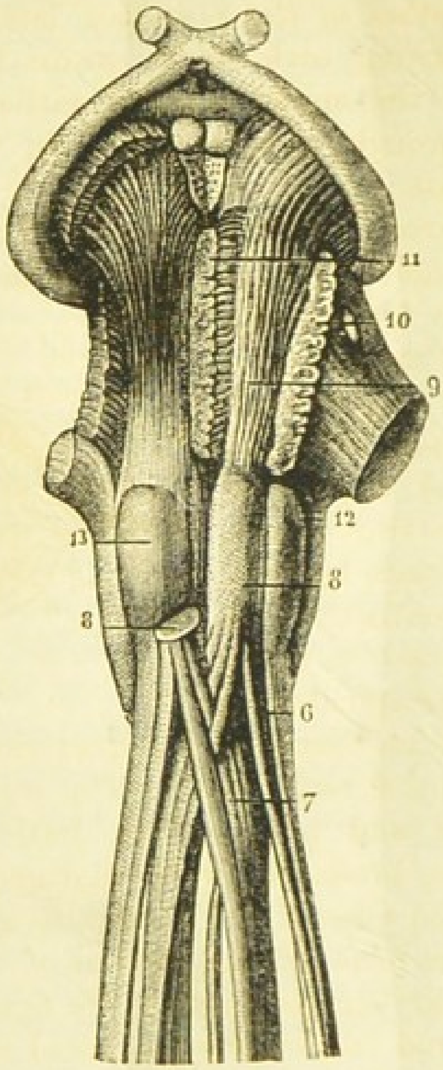


Fig. 250.*

VIEW OF THE CONSTITUENT CORDS OF THE SPINAL MARROW, SEPARATED, AND UNITING IN THE PYRAMIDS OF THE BRAIN.

6. Anterior cord dividing itself into two, of which the innermost contributes to the formation of the corresponding pyramid.
7. Middle or lateral cord, divided into four, which pass from the left to the right side, intersecting an equal number of similar ones coming from the opposite side, and taking the inverse direction.
8. The pyramids, of which the right is cut off immediately above the intersection, to show the olivary body (13) behind it.

* From Hirschfeld and Leveillé.

9. Left pyramidal bundle of fibres, traversing the pons Varolii, and proceeding to form the corresponding peduncle.
10. Section of the transverse superficial fibres of the pons.
11. Section of its deep fibres.
12. Left olivary body.

341. **Spinal Nerves.**—A series of nerves, called the *spinal nerves*, issue in pairs, one from each side of the spinal cord, each nerve having two roots ; one of which is implanted in the anterior, and the other in the posterior lateral fissure. These two roots, approaching each other, unite to form the nerve which issues from the spinal cord at either side, passing, as already stated, through a lateral hole in the bony envelope provided for its exit.

342. A transverse section of the cord and its envelopes, made at a point where a pair of nerves issue from it, is shown in fig. 251, where 1 represents the dura mater ; 2 and 3 represent the external and internal folds of the arachnoid, which is a double web, like a sheet of paper folded into two leaves, having a certain space between them. In the centre of the figure is represented a transverse section of the spinal cord having a deep median fissure on the posterior side, and a more shallow one on the anterior side. The substance of the cord consists of white and grey matter, but, contrarily to their arrangement in the brain, the white matter is exterior, and the grey interior. The quantity of the white greatly exceeds that of the grey. The form of the section of the grey matter is shown by the darkly shaded part of the figure. The space 7, between the internal fold of the arachnoid and the spinal cord, is filled with the cerebral fluid already described. The sheath formed by the continuation of the dura mater for the spinal nerve round the hole through which it issues, is shown at 9.

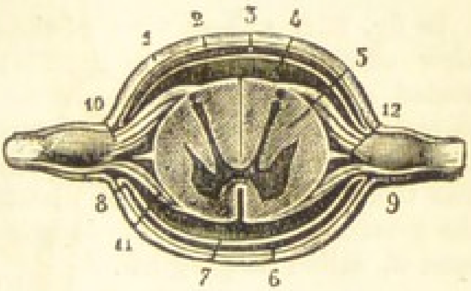


Fig. 251.*

343. The posterior roots, proceeding from the posterior lateral fissure, in which they are implanted in the lateral groove are shown at 10, and the anterior, less numerous and smaller, proceeding from the anterior lateral fissure at 11. These two roots unite to form the nerve at the point of exit. On either side of the spinal cord is placed a ligament, indicated

* From Hirschfeld and Leveillé.

in section at 12, called the denticulate ligament, which will presently be more fully explained.

The manner in which the spinal nerves are connected with the cord may be illustrated also by the geometrical figures, figs. 252 and 253.

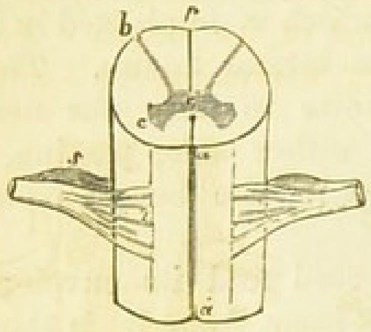


Fig. 252.

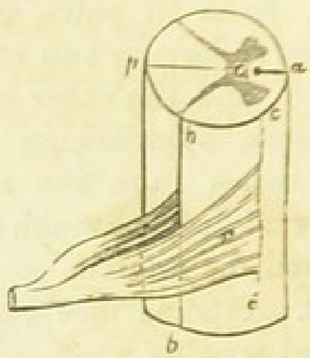


Fig. 253.

In fig. 252, a front view of the spine is supposed to be presented, and a view of the right side in fig. 253. The anterior median fissure is represented at *a a'*, and the posterior at *p*. The anterior lateral fissure is shown at *c c'*, with the anterior root of the nerve lodged in it, and the posterior lateral fissure at *b b'*, with the posterior root of the nerves also in it. The two roots unite at some distance from their insertion in the cord, and the posterior root, which is longer than the anterior, has an enlargement upon it, called its ganglion.

The fibres, constituting the larger and posterior root, are nerves of sensation, while those which constitute the lesser and anterior root are nerves of motion, as will be demonstrated hereafter.

344. Having thus described generally the cord and its appendages, their arrangement in the vertebral canal will be more clearly understood by reference to figs. 254, 255, 256, which represent a vertical section of the entire spinal cord, divided, as before, into three equal parts. The cord is supposed to be viewed from behind; and the posterior roots of the nerves are shown on the right side, but are removed on the left, in order to render visible the form and points of attachment of the denticulate ligaments. The points of attachment of these ligaments are indicated at 9, 9, 9; and it will be observed that they do not occur with regularity between nerve and nerve. The posterior roots of the right series of spinal nerves are shown at 10, 10, 10. The lateral fissure, in which the posterior roots of the left series of nerves (removed in the figure) are implanted, is shown at 11, 11, 11. The commencement of the anterior roots

of the left series of nerves is shown at 13, 13, 13. After issuing from the spine, each nerve divides, as shown at 14, into two branches,—a smaller posterior and a greater anterior branch, the latter being the continuation of the trunk.

345. The Spinal Cord, properly so called, terminates in a point, at 15, at a distance above the lower extremity of the vertebral column, equal to about a third of its length. From the lower part of the cord a bundle of nerves proceeds down-

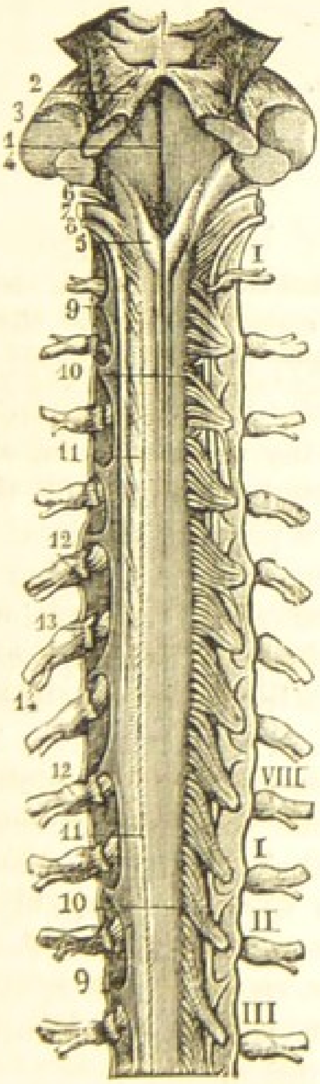


Fig. 254.*

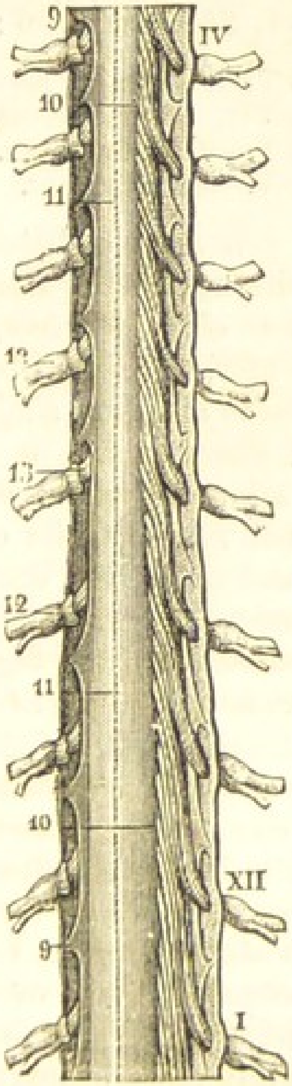


Fig. 255.*

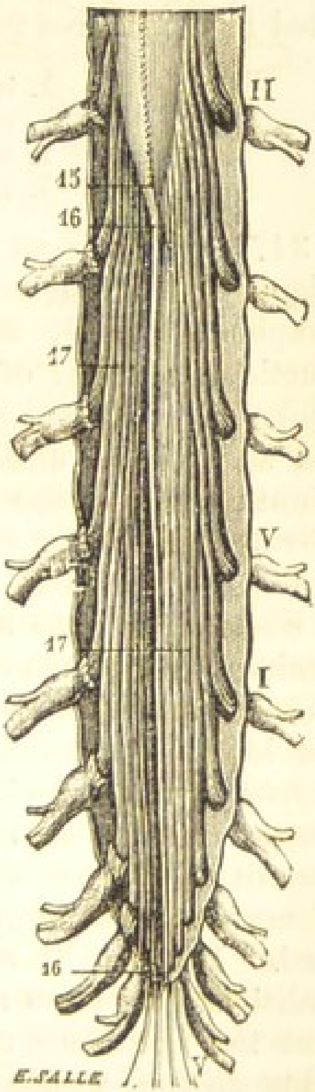


Fig. 256.*

wards, lying in juxtaposition, and having a general resemblance to a horse's tail, from which this part has received the name of *cauda equina*. The nerves which form the cauda being those which, had the cord been continued downwards, would have

* From the original of Hirschfeld and Leveillé.

issued in pairs laterally, like those above them, still do so, as will appear by reference to the figure. Each pair of nerves, on arriving at the lateral hole which corresponds to them, turn at right angles, and issue horizontally or obliquely through the holes. To retain the spinal cord more steadily in the centre of the vertebral canal, a single ligamentous thread (16, 16), called the central ligament of the cord, is stretched from the point of the cord to the lowest point of the vertebral canal.

346. The series of nerves which thus issue laterally from the spine are grouped, by anatomists, in four classes, thus indicated in the figures 254, 255, and 256 :—

I. to VIII.—Cervical nerves.
I. to XII.—Dorsal nerves.
I. to V.—Lumbar nerves.
I. to V.—Sacral nerves.

347. The nerves generally, whatever be their apparent origin, pass through the system in ramifications more or less complicated, and, like electric wires, only discharge their functions, whether of motion or sensibility, at their terminations. The nervous cords are thus subject to endless division and subdivision, until they become in many cases so infinitely minute as to escape all observation, even by the aid of the microscope. Since each fibre has its own peculiar destination and special function, and since this destination and function is in relation with the brain, it must be apparent that the various ramifications, in successively uniting together, as they approach their origin, can never be deprived of their proper functions, nor lose their individuality. It must not, consequently, be supposed that there is any analogy between the cases of blood-vessels running into each other, where the confluent streams are mixed, to form a single current after their union, and those of nerves coalescing, so that two or more fibres form a single cord. It must be considered, on the contrary, that in such coalition there is no actual mixture of nervous substance, and that the fibres are merely ranged side by side in mechanical juxtaposition, without any more intimate union.

348. These conclusions, which are derived from analogies of irresistible force, based upon the physiological properties of the nerves, are fully corroborated and confirmed by direct observation. Each nervous cord is ascertained to be a bundle of fibres enclosed in a common sheath, these component fibres being very numerous, and of unequal thickness.

In fig. 257 a nerve is represented, as drawn by Sir Charles

Bell, consisting of many cords, or funiculi, wrapped up in a common cellular sheath. A is the nerve, and B a single funiculus drawn out from the rest. Independently of the common sheath, or neurilemma, each particular component

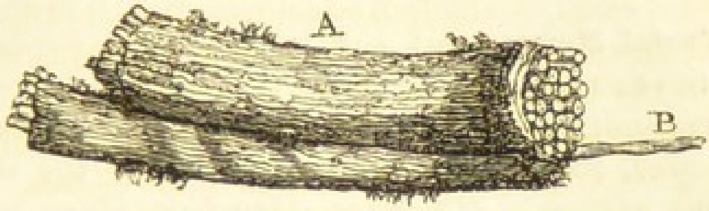


Fig. 257.

cord has a sheath of its own. All these sheaths are composed of the same fibrous tissue, which appears to be nothing more than a continuation of the tissue which constitutes the neurilemma or sheath of the spinal cord.

349. The proper substance of the nervous filaments is an assemblage of flexible and hollow fibres of extreme tenuity, which are juxtaposed in parallel directions, having a milk-white colour, and throughout the whole length of the cord are so independent, that they can be isolated one from the other.

Fontana, Remak, and Purkinje maintain that each of the constituent fibres of a nerve is cylindrical, and formed of two concentric tubes, one contained within the other. The central tube, consisting of a peculiar membrane, transparent and homogeneous, contains a whitish oleaginous humour, while the exterior tube is formed of a cellular substance.

Ehrenberg and the most eminent micrographers maintain that there are two orders of primitive nervous tubes, which they denominate *varicose* and *cylindrical*.

The varicose tubes consist of a series of alternate enlargements and contractions, whence they are sometimes called *articulated tubes*, and contain a peculiar transparent liquid, which these physiologists call the *nervous fluid*. The diameter of these tubes varies from the 1200th to the 37000th of an inch. They are smaller as they pass from the centre to the external part of the brain, so that their nodosity is scarcely visible in the grey part of the cerebral matter. They are found more particularly in the nerves of special sensation, and in the medullo-encephalic axis.

The cylindrical tubes are, as their name implies, uniform in diameter, and show no alternate enlargement and contraction like the former. They are filled with a white, viscid, and imper-

fectly transparent liquid, which flows out readily in globules. They are met with more especially in the nerves of the cerebro-spinal system ; in those of sensation as well as those of motion.

According to Dr. Mandl, the fibres of the nerves of motion are much thicker than those of sensation.

350. **Facial Nerves.**—It has been already explained that, although the muscles are the proximate causes of motion in the animal organisation, they have not themselves any original moving power, and only become active under the stimulus of the nervous system. Wherever, therefore, there are muscles there must necessarily be corresponding nerves; and the number and variety of these nerves, and their diffusion, will necessarily be proportionate to, and co-extensive with, the number, variety, and magnitude of the muscles.

Although it would not be compatible with the purposes to which this volume is directed, nor the limits within which it must be circumscribed, to supply a statement and exposition of the nerves which throw the numerous muscles of the body into action, it will, nevertheless, be useful and interesting to convey some idea of their distribution throughout the system, and of the manner in which they ramify over all those parts to which motion is to be conveyed, or from which sensation is to be transmitted.

The nerves which overspread the superficial muscles of the head, face, and neck, shown in fig. 53, are represented in fig. 258.

The principal of these, called the facial nerve, 258, [1], issues from an orifice under the ear called the stylo-mastoid foramen. It immediately gives off three branches, called the posterior auricular, 258, [2], the digastric, 258, [7], and the stylo-hyoid, 258, [8].

The posterior auricular branch turns immediately backward beneath the ear, and is joined by the auricular branch of the cervical plexus, 258, [3]. It throws out a branch, 258, [4], which supplies the occipital muscle ; another, 258, [5], which supplies the posterior auricular muscle; and a third, 258, [6], which supplies the superior auricular muscle.

The trunk, 258, [1], proceeding forwards towards the jaw, divides into two primary branches, the ramifications of which spread over the side of the head, face, and neck. These two primary divisions are called the temporo-facial 258, [9], and the cervico-facial, 258, [15] branches.

The temporo-facial branch (9), which is the largest of the three, spreads its ramifications over the entire side of the face, extending as high as the temple and as low as the mouth, and from the ear to the eye. The cervico-facial branch (15) is first directed towards the angle of the lower jaw (16 and 17), whence it throws out numerous ramifications, which overspread the muscles of the lower part of the cheek and chin, and others which descend towards the neck. Various other nervous trunks, variously denominated in anatomy from their local positions, may be seen to issue from foramina at 27, 25, 24, 22, 21, 19, 20, 28, and 18. Branches of

another nerve, called the cervical nerve, diverge in different directions from 32, some ascending to the ear and behind it, and anastomosing with

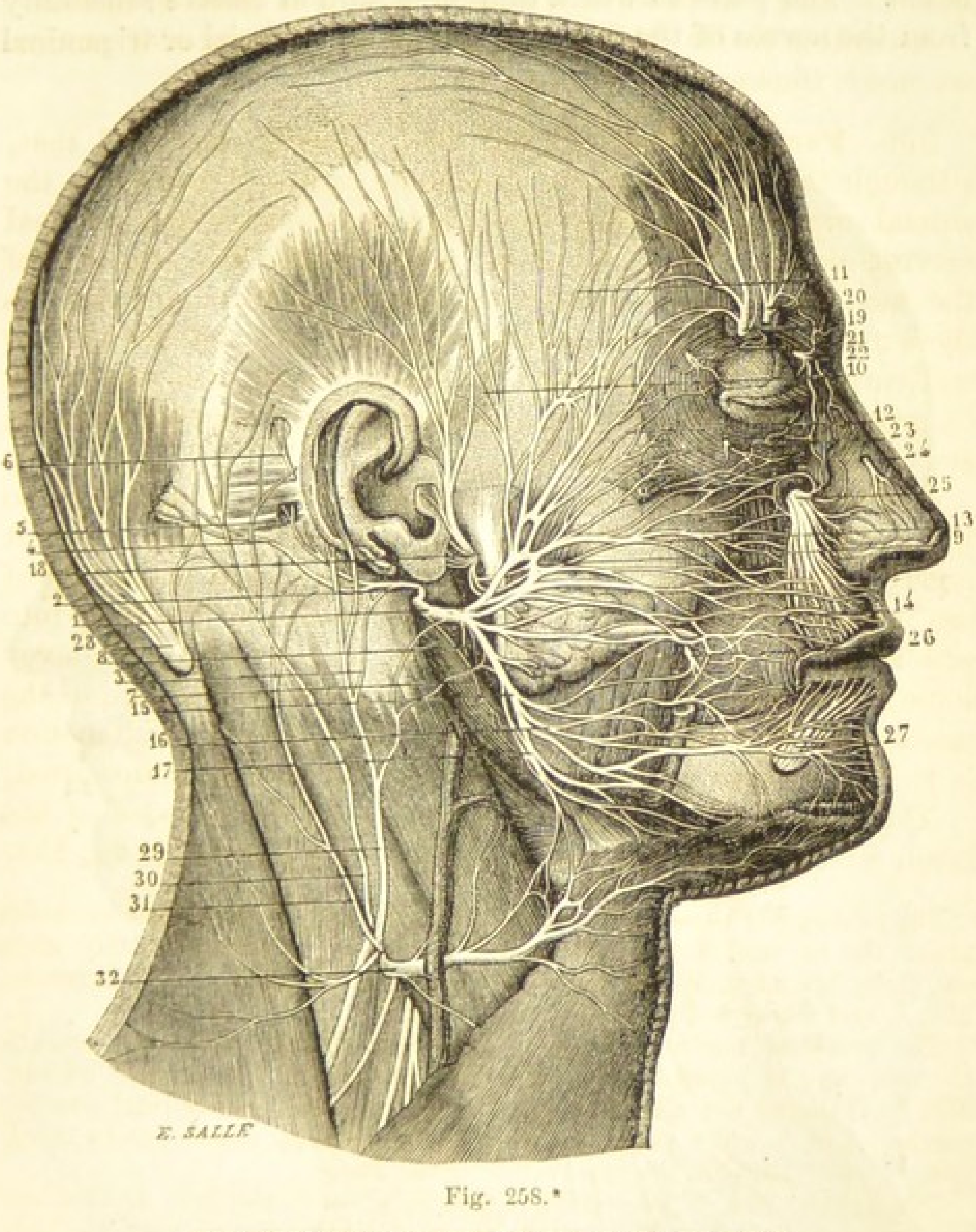


Fig. 258.*

THE SUPERFICIAL NERVES OF THE FACE AND HEAD.

the branches of the facial nerve ; others are thrown forwards to the front of the neck and the muscles under the jaw ; while others pass in the contrary direction to the back of the neck.

These nerves govern all the motions of the muscles of the scalp, the ear, the mouth, lips, nose, and eyelids, the integuments of the ear, and the upper part of the neck.

* From Hirschfeld and Leveillé.

The nerves here described, which are all ramifications of the seventh pair, are exclusively motor, including no sensitive fibres. The parts to which they give motion receive sensibility from the nerves of the fifth pair, called the trifacial or trigeminal

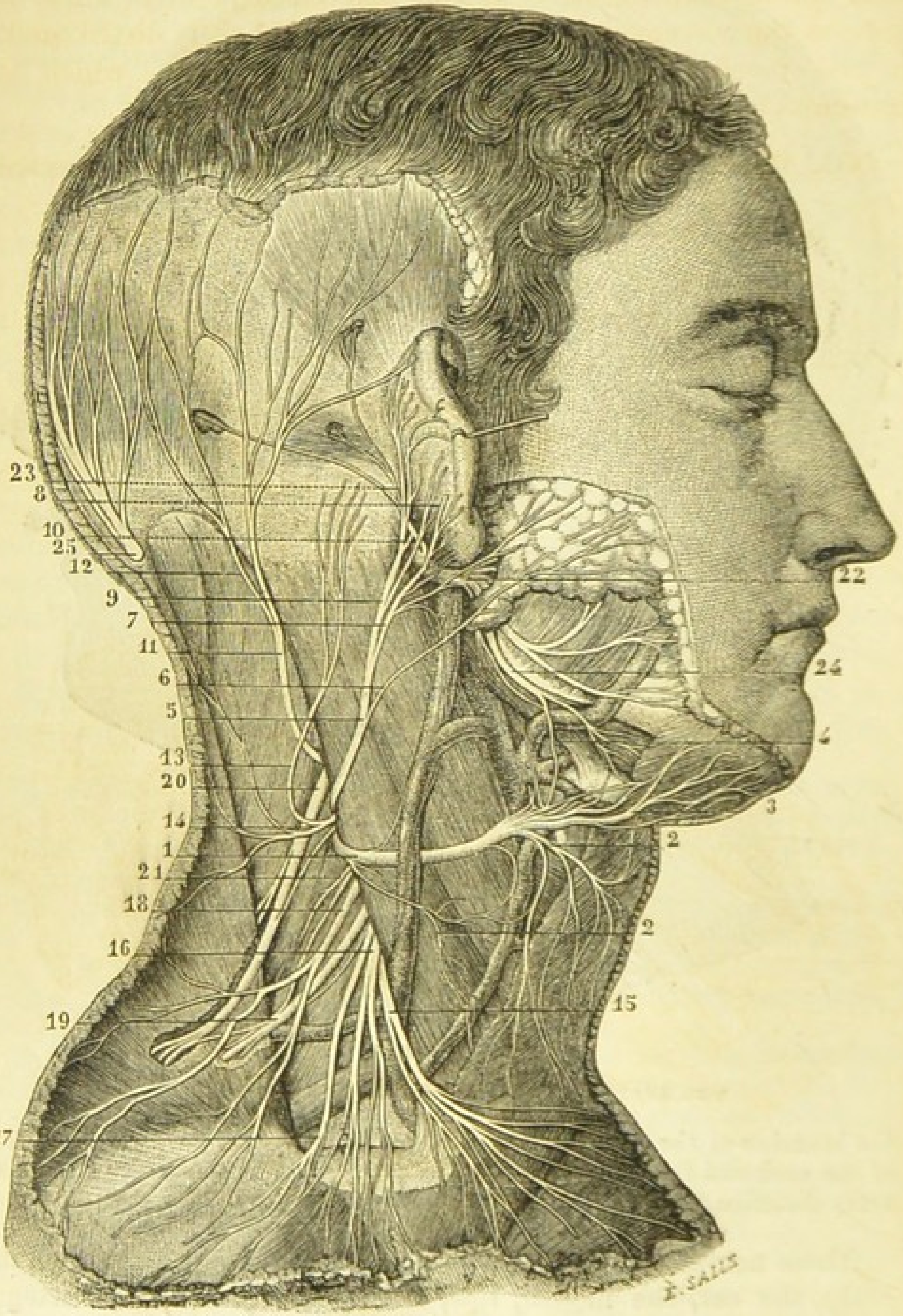


Fig. 259.*

CERVICAL NERVES.

* From Hirschfeld and Leveillé.

nerves. Thus the functions of motion and sensibility are in this case attached to different systems of nerves, while in the cases represented in the following figures of the cervical and other nerves, each cord is a compound one, which includes both motor and sensitive fibres ; and consequently while it governs the movements of the parts over which it is distributed, it also receives sensitive impressions from them, which it transmits to the nervous centre.

351. **Cervical Nerves.**—A system of nerves, also connected

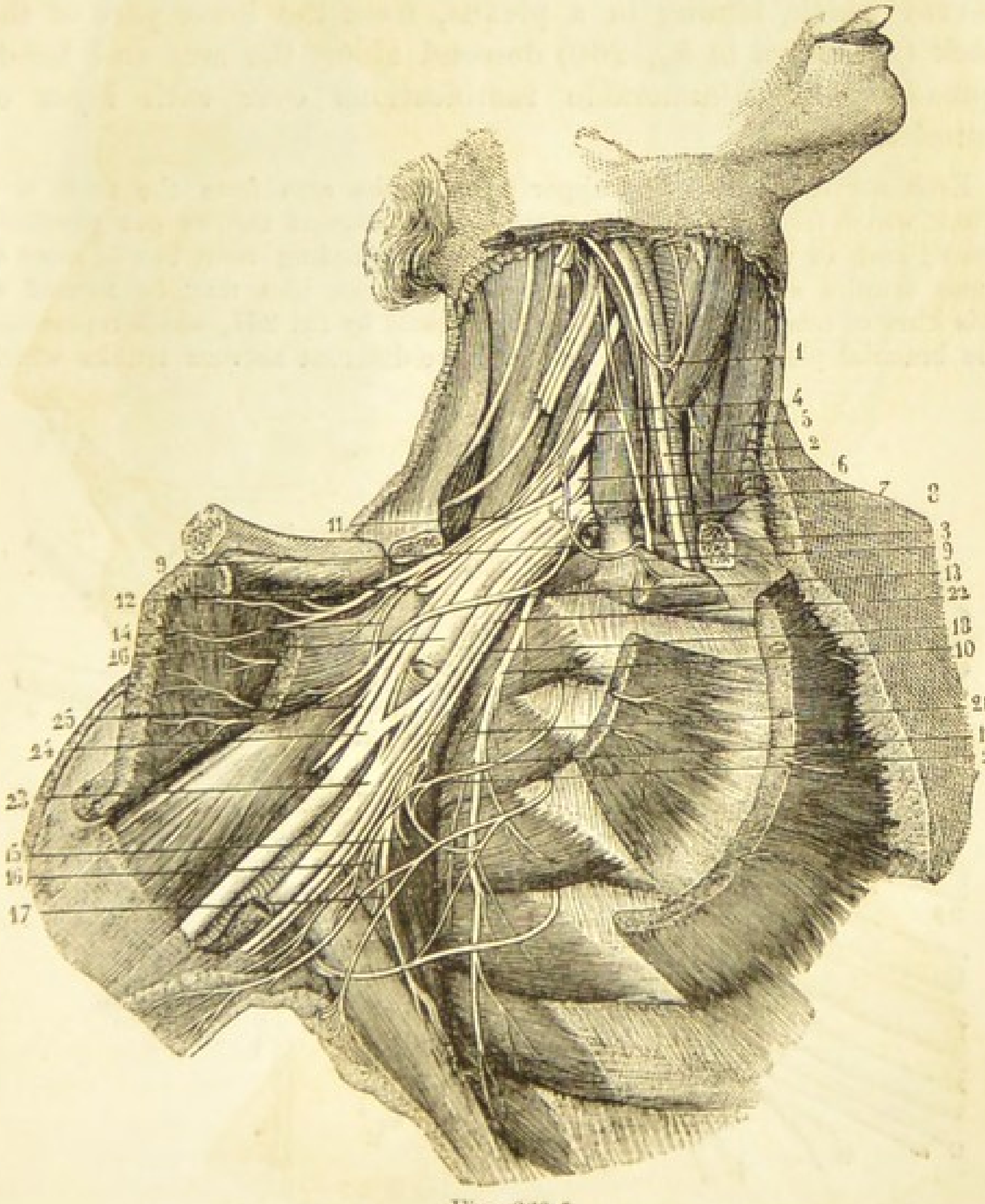


Fig. 260.*
THE BRACHIAL PLEXUS.

with the muscles of the neck and the lower part of the head,

* From the original of Hirschfeld and Leveillé.

called the *cervical plexus*, is represented in fig. 259. A transverse branch (1) is directed forwards towards the jaw, and diverges into two ramifications, one (2) descending along the neck, and the other (3) ascending along the jaw. A branch (5), called the auricular, ascends to the ear. Various other branches (15, 16, 17, 19) descend to the chest.

352. **Brachial Nerves.**—The numerous muscles which, in layer over layer, invest the bones of the arm and hand, are moved, as may be expected, by a corresponding multiplicity of nerves which, issuing in a plexus, from the lower part of the neck (as shown in fig. 260) descend along the arm and hand, spreading in innumerable ramifications over each layer of muscles.

Each nerve, entering the upper part of the arm from the neck, is a trunk which from one point to another in its descent throws out ramifications; and, in many cases, the branches proceeding from two or more of these trunks combine with each other. Some idea may be formed of this kind of complicated nervous ramifications by fig. 261, which represents the brachial plexus shown in fig. 260, the different nervous trunks which

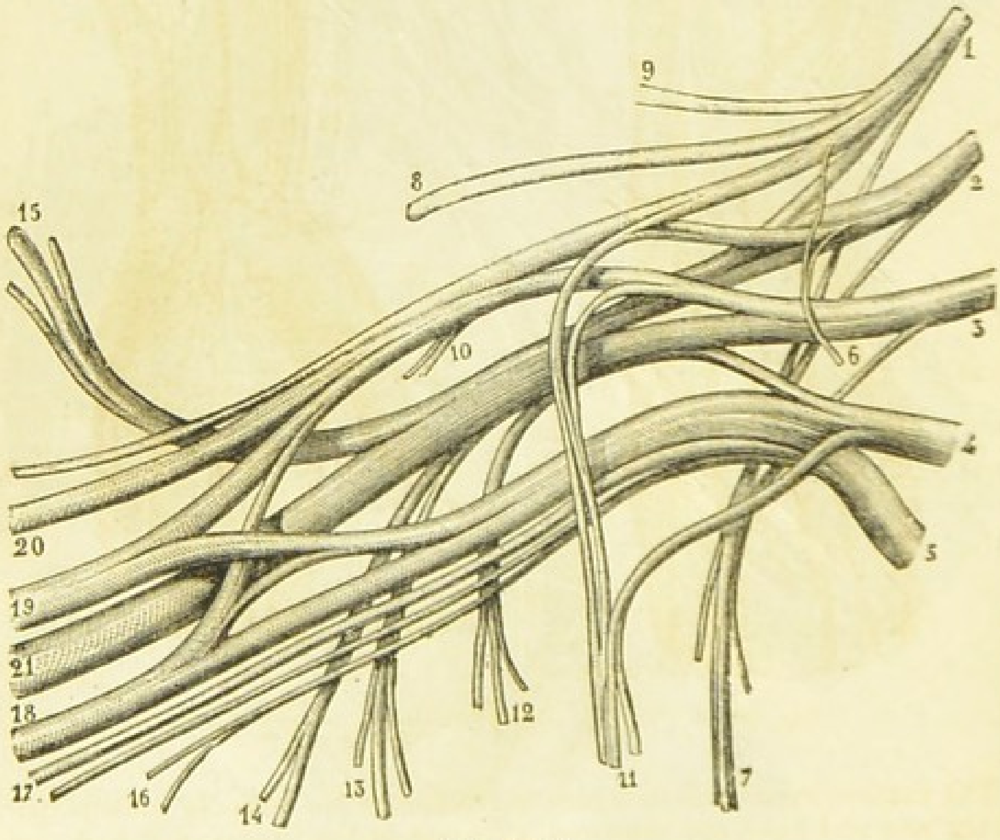


Fig. 261.*

compose it having been separated in order to show the origin of each of the collateral and terminal branches. Thus it will be seen that the

* From the original of Hirschfeld and Leveillé.

branch at 7 is formed by the anastomosis of branches from the trunks 1, 2, and 3, the branch 11 by a combination of ramifications from 1 2, 3, and 4, and so on.

The superficial nerves of the anterior part of the arm and hand are shown in figs. 262 and 263.

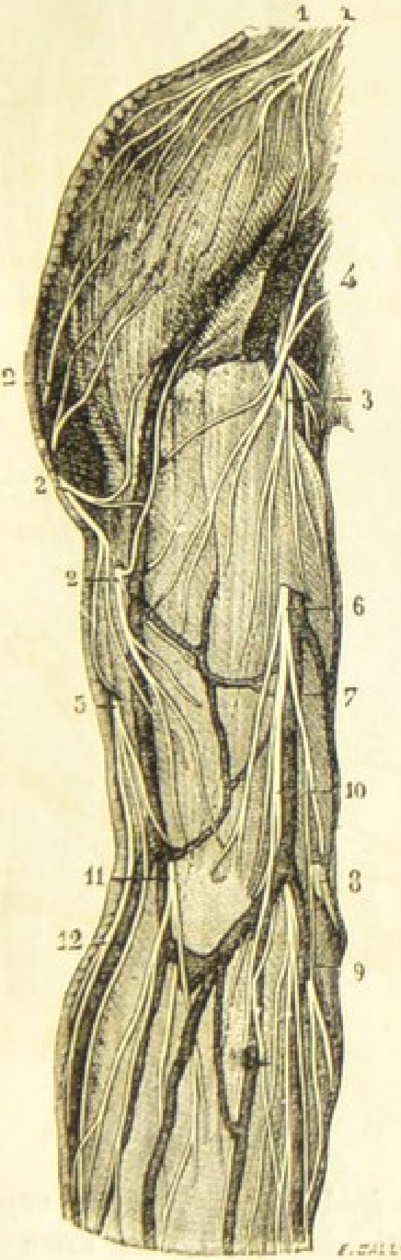


Fig. 262.*

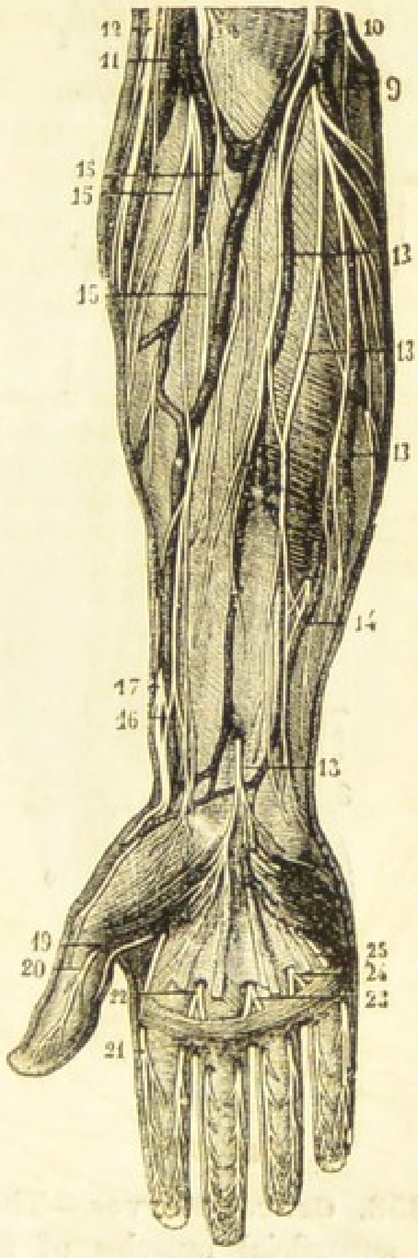


Fig. 263.*

The various ramifications which spread over the muscles of both parts of the arm and hand are rendered apparent in the figures, and each ramification has received special denominations from anatomists.

The nerves which supply the deeper muscles of the arm and hand, are shown in like manner in figs. 264 and 265.

* From Hirschfeld and Leveillé.

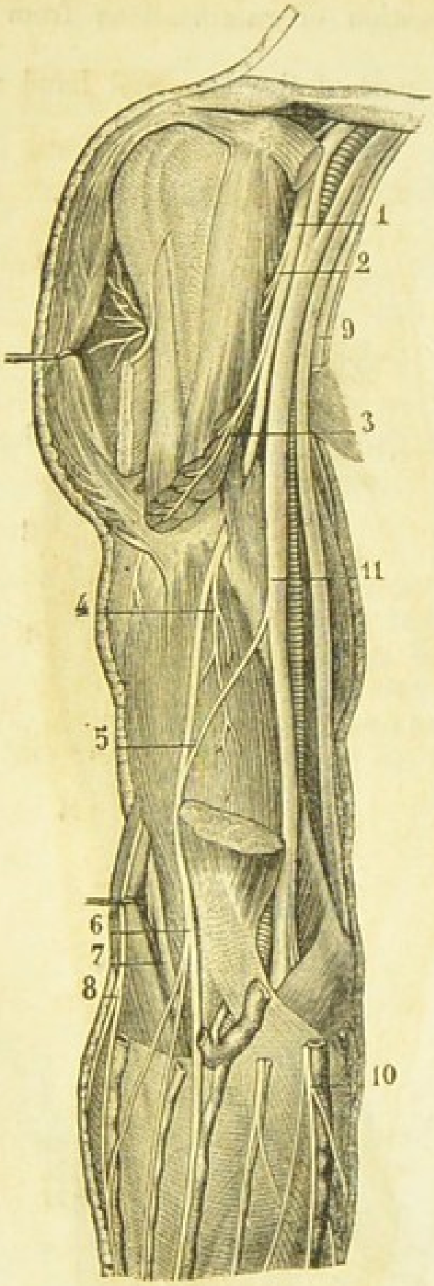


Fig. 264.*

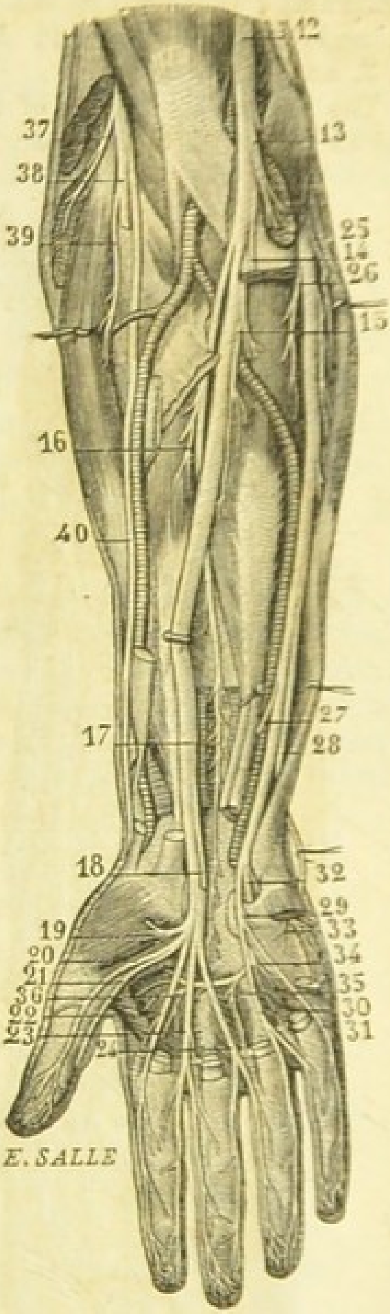


Fig. 265.*

353. **Crural Nerves.**—The principal nerves which supply the superficial muscles of the thigh down to the knee are shown by a front view in fig. 266, and by a side view in fig. 267.

The nerves in this, as well as in all the other figures, are represented as white cords, the veins being black, and the arteries being represented as a series of rings.

The nerves which supply the superficial muscles of the leg

* From Hirschfeld and Leveillé.

and foot are shown by a side view in fig. 268, and a back view in fig. 269.

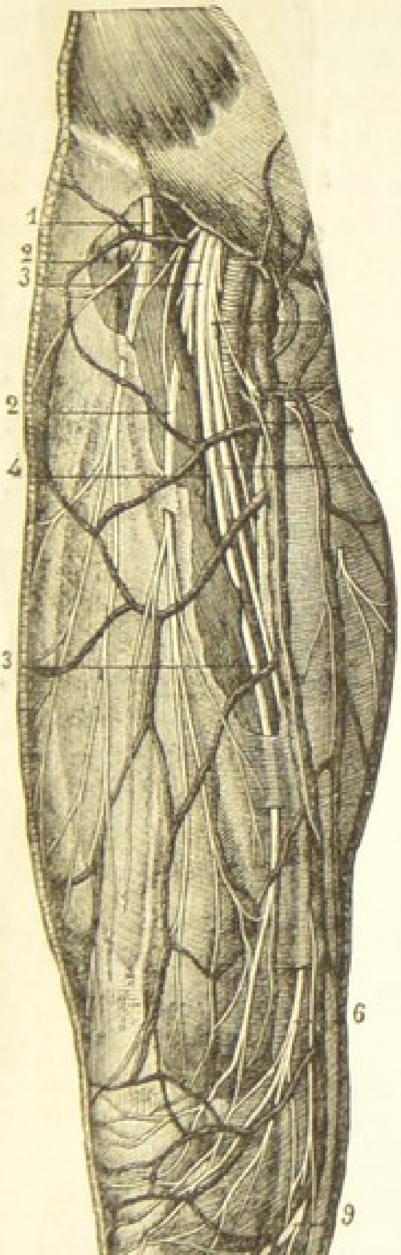


Fig. 266.*

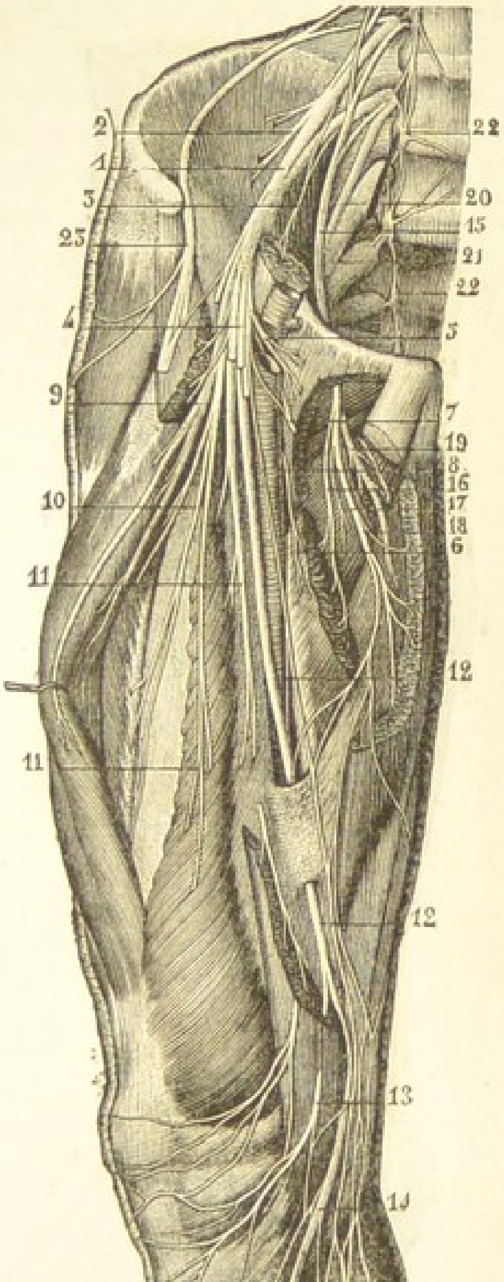


Fig. 267.*

THE GANGLIONIC SYSTEM.

354. This system, also called the *great sympathetic nerve*, consists of a series of small masses of nervous matter, called *ganglions*,† connected together by intermediate nervous cords in

* From Hirschfeld and Leveillé.

† This is a Greek word, signifying tumour or enlargement.

such a manner as to form one continued chain communicating, in the one part by anastomoses with almost all the nerves

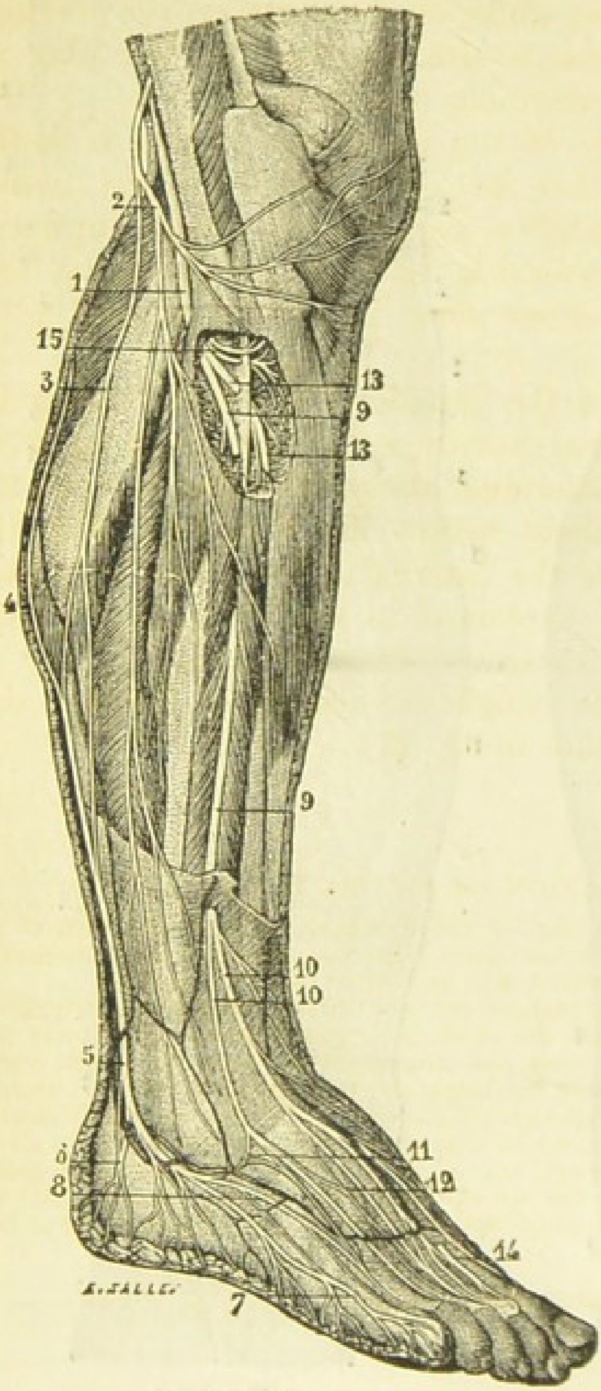


Fig. 268.*

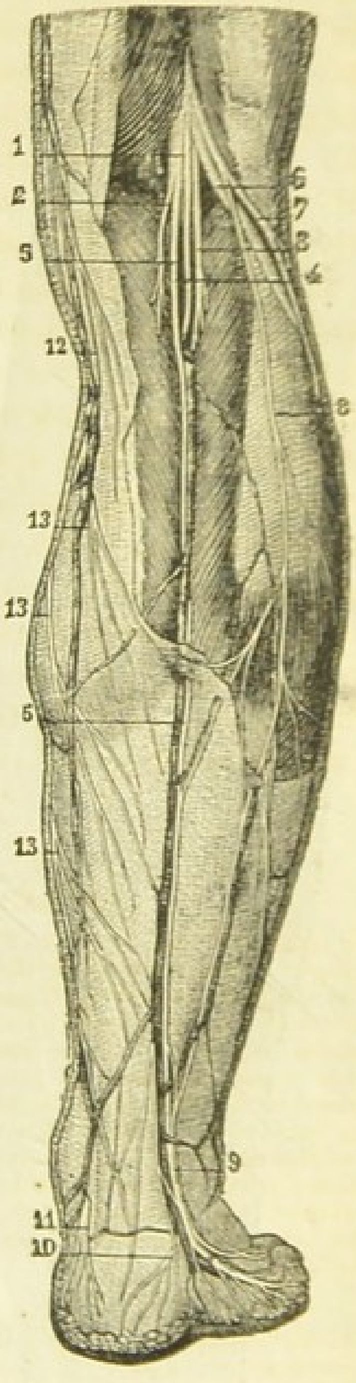


Fig. 269.*

of the cerebro-spinal system, and on the other spreading themselves in innumerable fibres over all the organs of the involuntary functions.

355. **The Sympathetic Nerve,** therefore, presides over the

* From the original of Hirschfeid and Leveillé.

most important organic phenomena—the functions of the viscera, whose assemblage forms the apparatus of digestion, respiration,* circulation, and secretion, which are independent of the will or consciousness; while, on the contrary, the province of the cerebro-spinal system is circumscribed by the play of the organs of sensation, perception, and motion.

356. The principal part of the ganglionic system is distributed symmetrically on either side of the median plane, immediately in front of the vertebral column. It extends upwards into the cranial, and downwards into the pelvic cavity, and presents numerous anastomoses along its course, as well as at its extremities.

357. A general view of the ganglionic system, showing its anastomoses with the spinal nerves, is represented in fig. 270. The chain of ganglions extending along the right side of the vertebral column, with their nerves anastomosing with the spinal, and spreading over the internal organs, will be recognised by the indications explained in the description of the figure.

The superior part of the ganglionic system of the left side will also be seen by reference to fig. 271.

EXPLANATION OF FIGURE 270.

The object of this figure is to display the vast assemblage of the parts of the ganglionic system, showing its connections with the principal cephalic nerves, such as the pneumogastric, trigeminal, &c., and with the spinal nerves.

PREPARATION.—The anterior and lateral parts of the right side of the trunk, the corresponding portion of the base of the skull, the right branch of the lower jaw, and the zygomatic arch of the same side are removed. Several of the organs contained in the abdomen, the chest, the head, and the face have been cut away or drawn back so as to display the right ganglionic chain from the base of the skull to that of the coccyx. The connections of this chain, on the one hand, with all the spinal and some of the cerebro-spinal nerves, such as the trigeminal, the glosso-pharyngeal, the pneumogastric, the spinal accessory, and the hypoglossal; and on the other hand, with all the ganglions and extra visceral plexus, have been preserved.

ACCESSORY PARTS.

a. Lacrymal gland.
b. Sublingual gland.
c. Submaxillary gland.
d. Thyroid body.
e. Trachea, of which the right bronchus is cut at its origin and slightly turned back, so as to show at the same time its membranous and cartilaginous parts.
f. Œsophagus passing through the diaphragm.
g. The stomach, hooked back to the left and cut open towards the pylorus so as to display the origin of the coronary stomachic plexus and the distribution of the two pneumogastric nerves.

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* Respiration is also under the influence of the cerebro-spinal system, as will presently be shown.

h. Several intestinal convolutions spread out so as to show the superior mesenteric plexus.
i. The transverse colon.
j. The sigmoid flexure.
k. The rectum.
l. The bladder half inflated.
m. The urethra.
o. The seminal vesicle.
p. The vas deferens.
q. The spermatic cord.
rr. The diaphragm.

VASCULAR SYSTEM.

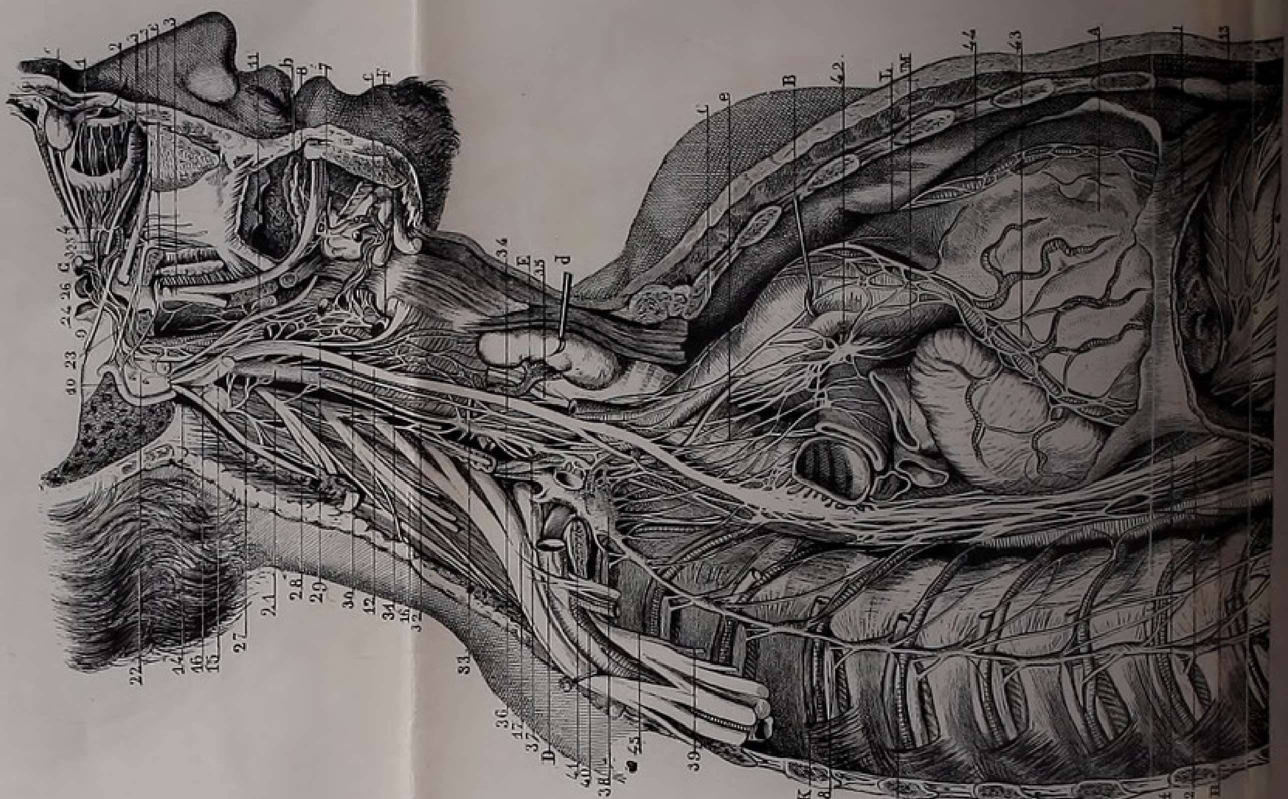
A. The heart slightly drawn back to show the chief part of the cardiac and its secondary coronary plexus of nerves, right and left.
B. The arch of the aorta hooked back.
C. The brachio-cephalic trunk.
D. The subclavian artery, a part of which has been removed to disclose the inferior cervical ganglion.
E. The inferior thyroid artery in connection with the middle cervical ganglion.
F. Part of the external carotid artery, some branches of which have been preserved to show the nervous plexus of the same name which interlace them.
G. The internal carotid artery maintained in its channel and cut at its two extremities.
H. The thoracic aorta passing below the diaphragmatic opening.
I. The abdominal aorta.
J. The common iliac artery.
K. The intercostal vessels.
L. The trunk of the pulmonary artery, the right branch of which is cut.
M. The superior vena cava cut at its origin.
N. The inferior vena cava.
O. The pulmonary veins.

CEREBRO-SPINAL SYSTEM.

1. The globe of the eye, from which a part of the sclerotica and cornea have been removed, to show the ciliary nerves, which, after having perforated the posterior part of the sclerotica, pass along the choroid and terminate in the ciliary ganglion.
2. Nerve of the inferior oblique muscle, from which issue parts of the motor root of the ophthalmic ganglion.
3, 3, 3. The three branches of the trigeminal nerve in connection with most of the cranial ganglions.
4. The ophthalmic ganglion.
5. The spheno-palatine ganglion.
6. The otic ganglion.
7. The submaxillary ganglion.
8. The sublingual ganglion.
9. The external motor ocular nerve.
10. The facial, anastomosing with the otic and spheno-palatine ganglions.
11. The glosso-pharyngeal.
12, 12. The right pneumogastric.
13. The left pneumogastric spreading over the anterior surface of the stomach.
14. The spinal accessory.
15. The hypoglossal.
16, 16. The cervical plexus.
17. The brachial plexus.
18, 18. Intercostal nerves.
19, 19. Lumbar plexus.
20. Sacral plexus.

GANGLIONIC SYSTEM.

21. Superior cervical ganglion. It gives origin above to the two carotid branches which form the carotid plexus around the carotid artery, from which emanate or terminate anastomoses with the following nerves:—
22. The nerve of Jacobson.



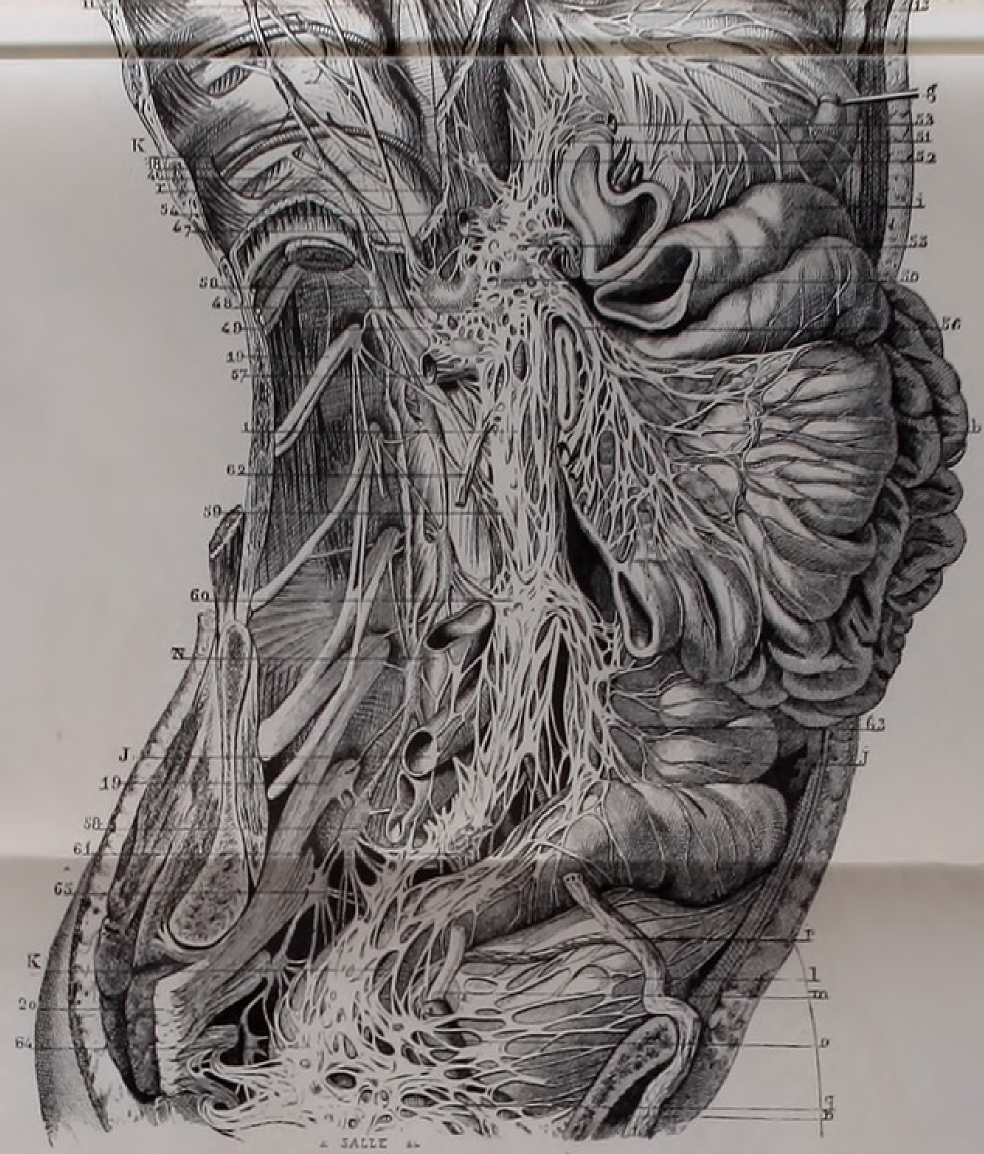


Fig. 270.

GENERAL VIEW OF THE GANGLIONIC SYSTEM,

Showing its connection with the Cranial and Spina. Nerves, reproduced from the original, drawn by M. Leveillé, from a preparation made by M. Hirschfeld, with the permission of the authors and of M. J. B. Baillière, the publisher.

[To face page 278.]

23. The carotid filament of the Vidian nerve.
24. The external ocular motor.
25. The ophthalmic ganglion.
26. Filament for the pituitary gland.
27. Anastomoses of the superior cervical ganglion with the first cervical pair.
28. The pharyngeal and carotid branches.
29. The pharyngeal and intercarotid plexus.
From the latter emanate secondary plexus, which interlace all the branches of the external carotid, as may be seen in the figure in the case of the facial and lingual arteries.
30. Laryngeal branch connected with the external laryngeal of the pneumogastric, to form the laryngeal plexus of Haller.
31. The superior cardiac nerve.
32. Cords connecting the superior cervical ganglion with
33. The middle cervical ganglion, among the internal branches of which may be observed
34. The anastomosis, with
35. The recurrent nerve,
36. The middle cardiac nerve, and several filaments which interlace the inferior thyroid artery, a branch of the subclavicular artery. The external branches of the middle cervical ganglion throw themselves into the brachial plexus.
37. Cord joining this ganglion with
38. The inferior cervical ganglion.
40. Filaments of the latter around the subclavian and vertebral arteries.
41. Branch anastomosing with the first intercostal nerve,
42. Cardiac plexus and ganglion.
43. 44. Secondary plexus of the right and left coronary arteries.
45. 46. Thoracic ganglionic chain. It is connected without with the intercostal nerves. Within, the first five ganglions furnish numerous very delicate filaments, of which some are thrown into the cardiac plexus, others into the pneumogastric, and others upon the aorta and into the periosteum of the vertebræ. The five lower ganglions give internal branches, which anastomose with each other, and form
47. The great splanchnic, which passes through the diaphragm, to find its way to
48. The corresponding semilunar ganglion.
49. The little splanchnic formed by one or two branches issuing from the last two thoracic ganglions. This nerve presents here a slight enlargement assisting in the formation of the renal and solar plexus.
50. Solar plexus formed by a mass of ganglions, and by the interlacing of large intermediate branches with the right and left semilunar ganglions. This plexus receives
51. The anastomoses of the pneumogastric, and
52. Of the phrenic nerve, which presents at this place the diaphragmatic ganglion. The solar plexus furnishes the following secondary plexus :—
53. The stomachic coronary,
54. The hepatic, the splenic, and
56. The superior mesenteric. These four great plexus, as well as all the other visceral plexus, interlace the arteries whose names they bear.
57. The renal plexus.
58 to 58. Lumbar ganglionic chain. It anastomoses without, with the lumbar nerves, and furnishes within, several branches, which, after having anastomosed with those of the opposite side, and with a considerable prolongation of the solar plexus, form
59. The lumbo-aortic plexus. This last presents generally two flat enlargements, one (60) above, and the other (61) below the bifurcation of the aorta. It supplies (62) the spermatic, and (63) the inferior mesenteric plexus. Below its inferior enlargement, the lumbo-aortic plexus bifurcates, embracing the rectum, and throws itself into the hypogastric plexus.
64. The hypogastric plexus, formed by the preceding bifurcation, by the visceral branches of the sacral plexus, by several branches proceeding from the sacral and lumbar ganglions, and, in fine, by the termination of the inferior mesenteric plexus. It produces the vesical, prostatic, and spermatic plexus, and concurs with other nerves proceeding from the renal and lumbo-aortic plexus, in the formation of the plexus of the spermatic cord.
65. The sacral ganglionic chain. It anastomoses without with the sacral plexus. Within, its branches anastomose with each other, and with those of the opposite side, and throw themselves into the hypogastric plexus. The ganglionic system terminates with the coccygeal ganglion, at the lowest limit of the figure.

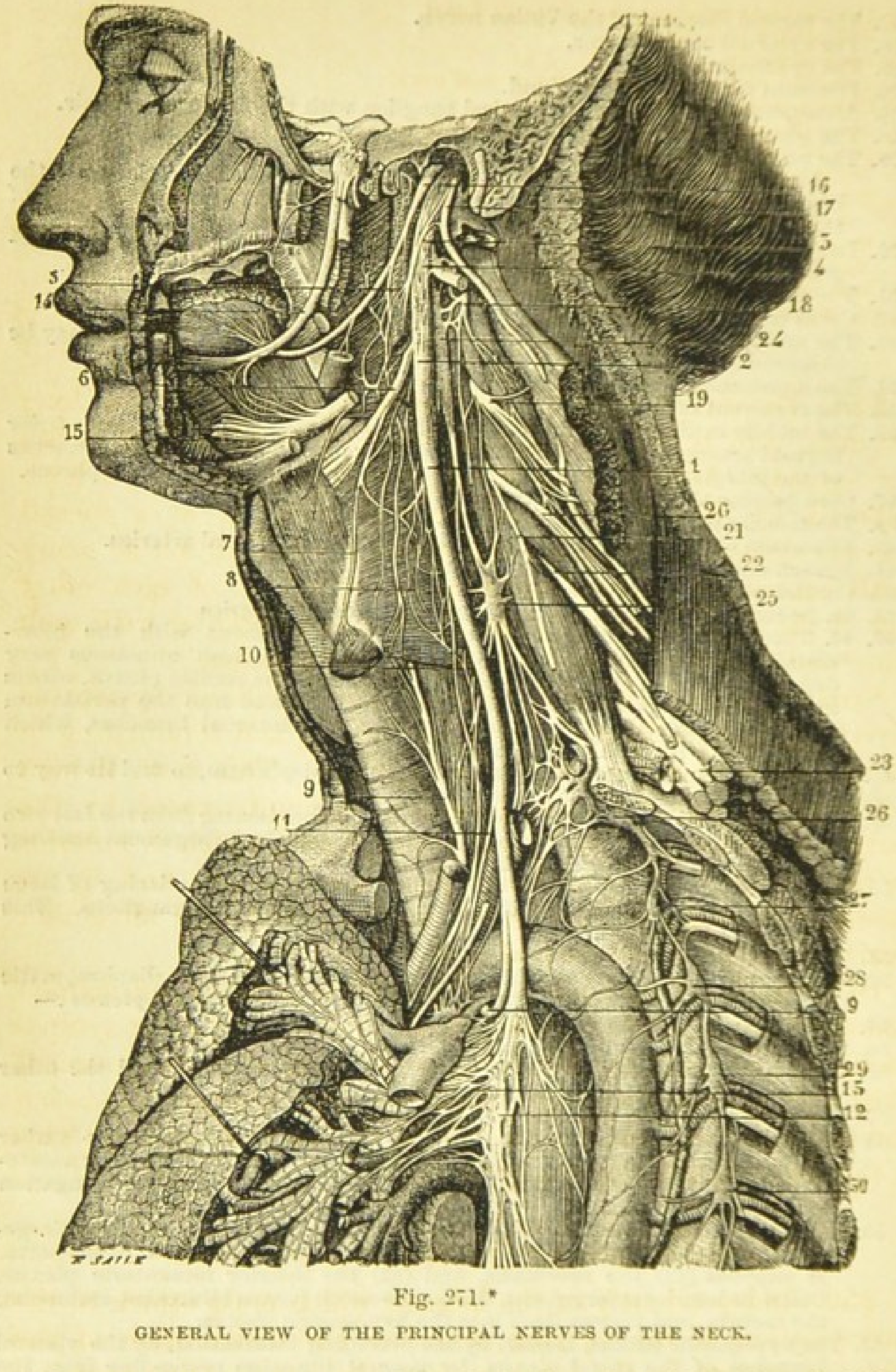


Fig. 271.*

GENERAL VIEW OF THE PRINCIPAL NERVES OF THE NECK.

1. Pneumogastric nerve, or, tenth cerebral; the principal branches of which anastomose with the filaments of the great sympathetic, and spread over the lungs and stomach.

6, 7. Branches of the pneumogastric passing to the larynx.

9, 9. Recurrent nerve, being a branch of the pneumogastric, which is bent upwards under the aorta, from the top of the thorax to the larynx.

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* Reproduced from the figures of Messrs. Hirschfeld and Leveillé.

10, 11. Cardiac branches passing to the heart.
13. Pulmonary plexus.
14. Lingual nerve.
15. Terminal part of the great hypoglossal nerve.
16. Glosso-pharyngeal nerve.
17. Spinal accessory or eleventh cerebral nerve.
18. Second cervical nerve.
19. Third cervical nerve.
23. Sixth, seventh, and eighth cervical nerves, joining with the first dorsal nerve to form the brachial plexus.
24. Superior cervical ganglion of the great sympathetic.
25. Middle cervical ganglion of same.
26. Inferior cervical ganglion of same.
27, 28, 29, 30. Dorsal ganglions.

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358. The origin of the ganglionic system has been long disputed, and is still a question upon which physiologists are not agreed. According to Winslow and Reil, who have been followed by Bichat, the ganglionic is regarded as a special nervous system. The ganglions which compose it are so many small centres of nervous influence independent of each other and of the cerebro-spinal system, and communicating with each other and with the latter by intermediate branches.

Sarlandière and Burdach consider the ganglionic system as deriving its origin from the internal organs, and terminating in all the points of the cerebro-spinal system. This view, though not much favoured by physiologists, is countenanced by the early development of the great sympathetic, which is anterior to that of the other parts of the nervous system, and by its existence in acephala and other species which are altogether deprived of the cerebro-spinal axis.

Other anatomists, ancient and modern, maintain an opinion diametrically opposed to this, which regards the great sympathetic as emerging by numerous roots from the cerebro-spinal axis, and, after undergoing remarkable modifications in passing through the ganglions, terminating in the internal organs. This is the doctrine most generally received.

NERVOUS SYSTEMS OF INFERIOR ANIMALS.

359. Independently of the interest which must attach to the investigation of the varying structure and distribution of the nervous system in the lower species, the comparative anatomy of the encephalon and its appendages derives great importance from the instrument into which it has been converted with such signal success in determining the functions of the several parts of the system. Without a general knowledge of the comparative anatomy of the brain, such observations would supply no

conclusive result. It is, therefore, important here, before noticing the discoveries which have been made respecting the functions of the nervous system, briefly to explain the principal differences which are observed in the cerebral organs of the inferior animals compared with man, and with each other.

360. The nervous system of mammifers, birds, reptiles, and fishes, is constructed upon the same general plan, and consists of the same chief parts as have been described in the case of the human race. In all there is a cerebro-spinal axis, including cerebrum, cerebellum, medulla oblongata, and spinal cord, with their appendages and divergent nervous trunks. In all there is also a ganglionic system; and the nerves which issue from the former have the properties characteristic of animal life, while those which issue from the latter have the properties of organic life, as in the nervous system of the human organism.

361. Nevertheless, there are considerable differences, as well between the human encephalon and that of inferior classes, as between those of inferior classes compared one with another.

Even upon a superficial view of the human encephalon compared with those of inferior animals, it will appear that the cerebral hemispheres are comparatively more extensive, that their convolutions are in general more numerous and complicated—presenting, consequently, a proportionately greater extent of surface; and, in fine, that while in man they completely overlap the cerebellum and all subordinate parts projecting more or less beyond them, they leave, in all inferior species, a portion of this part of the encephalon uncovered, and the portion so exposed is greater and greater as we descend in the scale of organisation.

When the human encephalon is viewed from above, nothing is visible between the extreme limits before and behind save the convolutions of the cerebrum (fig. 240). If it be viewed upon its base (fig. 244), the cerebrum is seen (244, [3]) projecting sensibly beyond the extreme limits of the cerebellum.

362. **Quadrumana.**—In the quadrumana, the class which bears the closest analogy to the human race, the encephalon viewed from above (fig. 272), and from below (fig. 273), presents the same general aspect as the human encephalon; but the cerebellum is seen, in fig. 272, from above projecting beyond the hemispheres of the cerebrum. The convolutions also are less numerous and complicated; while in the case of the human encephalon viewed upon its inferior surface (fig. 244), the

cerebrum appears beyond the cerebellum, no such appearance is

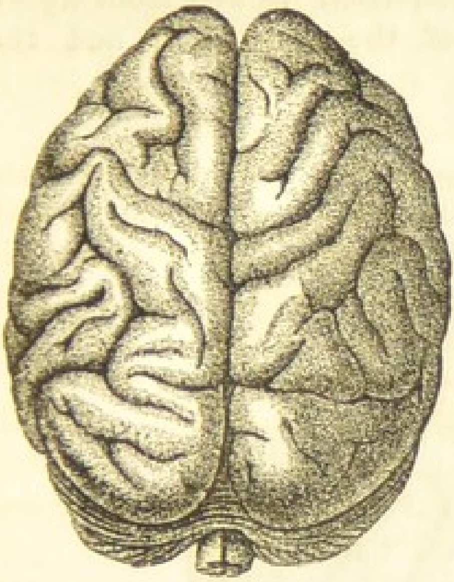


Fig. 272.*

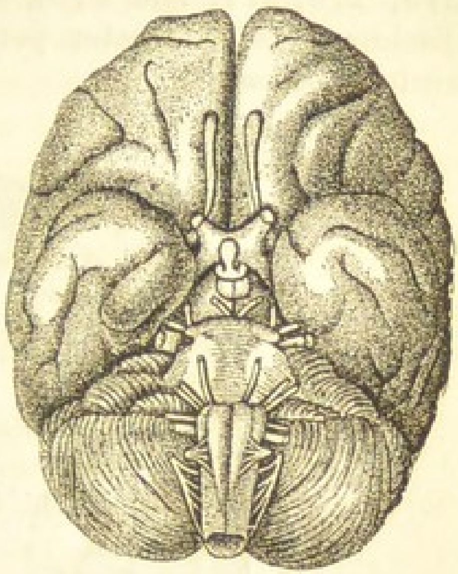


Fig. 273.*

ENCEPHALON OF THE ORANG-OUTANG.

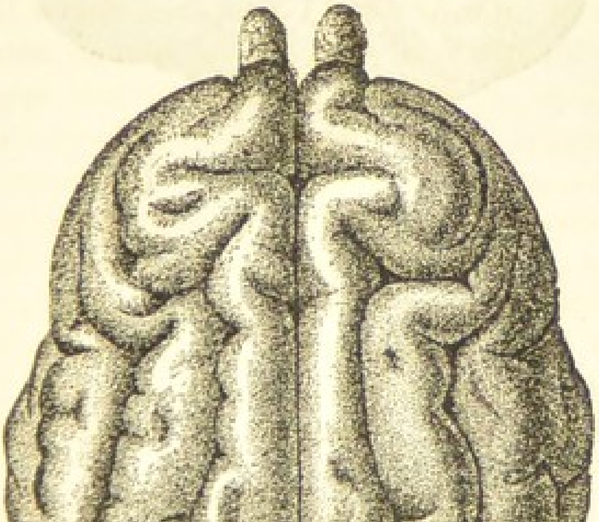


Fig. 274.†
ENCEPHALON OF THE LION REDUCED.

observed on the base (fig. 273) of the encephalon of the quadrumana.

* Treviranus. † Leuret.

363. **Carnivora.**—In the case of the carnivora (figs. 274, 275, 276, 277, and 278), the encephalon viewed from above discloses a still greater portion of the cerebellum and the medulla oblongata.

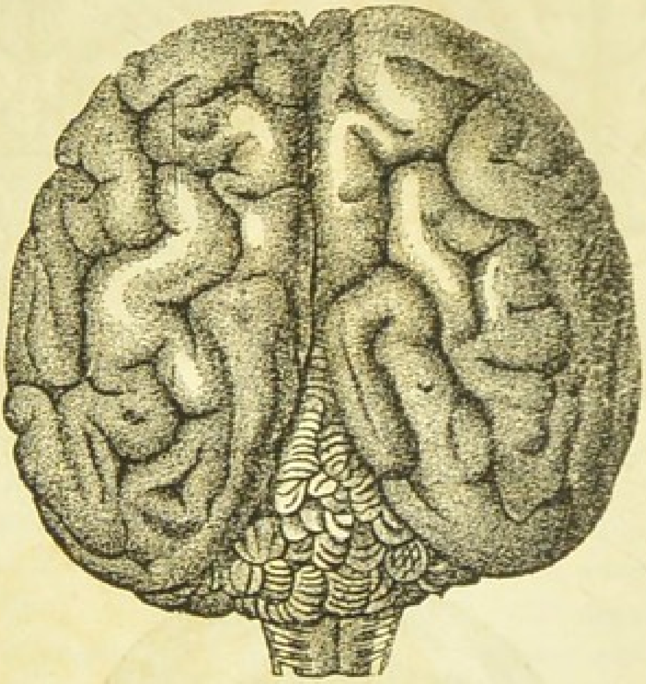


Fig. 275.*
ENCEPHALON OF THE SEAL.

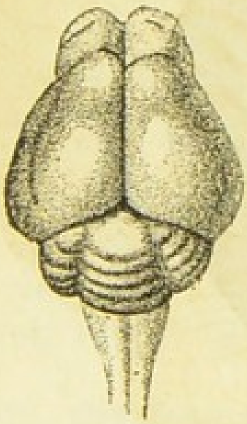


Fig. 276.*
ENCEPHALON OF THE HEDGEHOG.

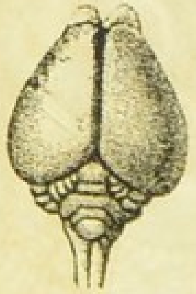


Fig. 277.*
ENCEPHALON OF THE MOLE.

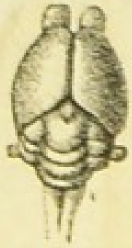


Fig. 278.*
ENCEPHALON OF THE BAT.

364. **Marsupialia.**—In the case of the marsupiata (fig. 279),

* Leuret.

the disclosure not only of the cerebellum is complete, but also of the parts above it.

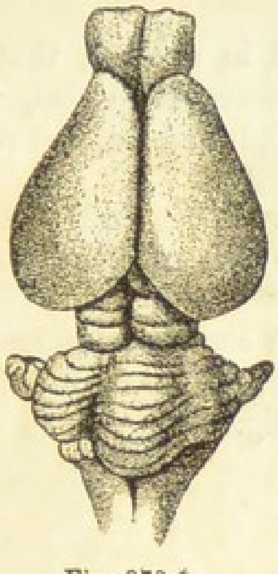


Fig. 279.*
ENCEPHALON OF THE OPOSSUM.

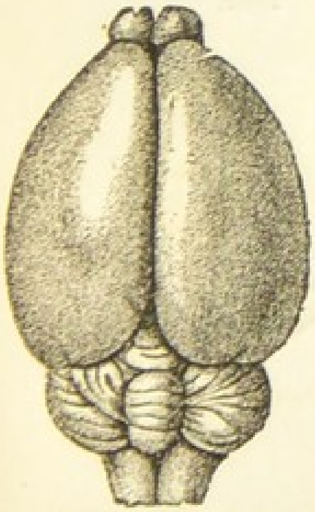


Fig. 280.*
ENCEPHALON OF THE BEAVER REDUCED.

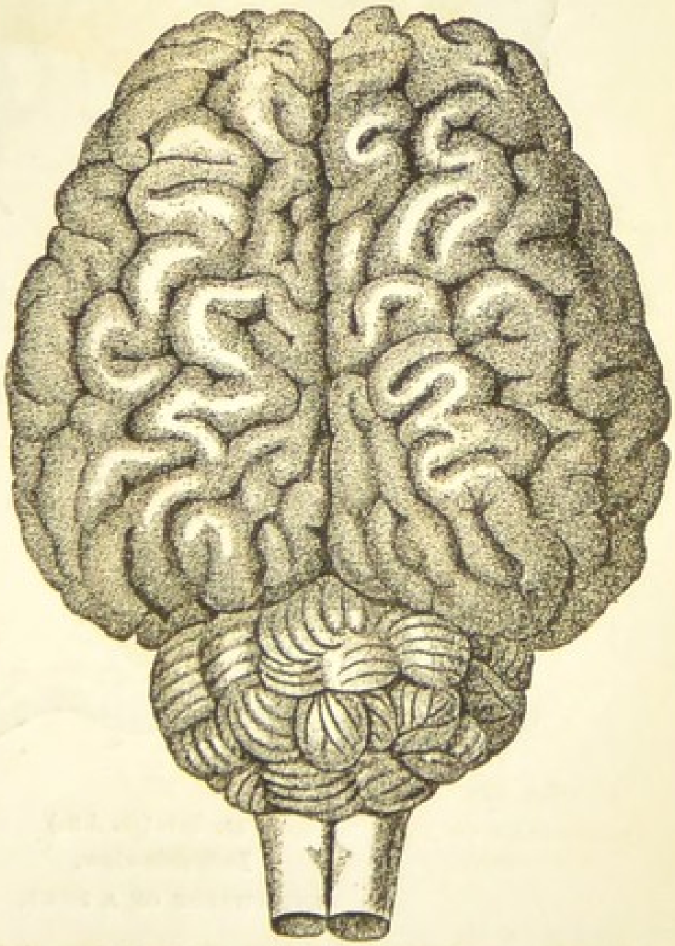


Fig. 281.*
ENCEPHALON OF THE GIRAFFE REDUCED.

* Owen.

365. **Rodents.**—In the rodents (fig. 280), the cerebellum is half exposed, and in the ruminants more than half exposed, (fig. 281).

It may be observed in general, that, in proportion as the cerebral hemispheres decrease in size, the subordinate parts, such as the corpora quadrigemina, are relatively enlarged.

366. **Birds.**—In birds (fig. 282) the cerebrum is so far decreased as to disclose not only the cerebellum, but also the corpora quadrigemina.*

The encephalon of a common domestic fowl is shown by its superior surface in fig. 282, by its inferior surface in fig. 283, and by a side view in fig. 284.

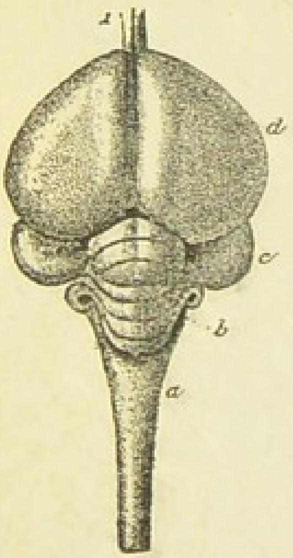


Fig. 282. (R. An.)
Superior Surface.

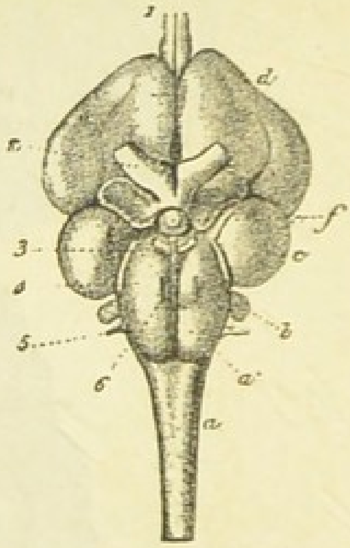


Fig. 283. (R. An.)
Base.

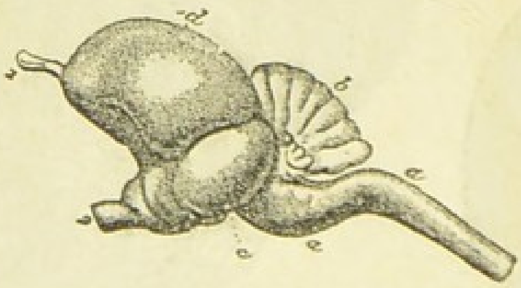


Fig. 284. (R. An.)
Left side-view.

ENCEPHALON OF A FOWL.

* Properly these parts of the brain in birds and inferior species are called bigemina, two only being found instead of four.

The following are the parts designated in this as well as all the succeeding figures :—

a. The spinal cord.
a[1]. The medulla oblongata.
b. The cerebellum.
c. The quadrigeminal tubercles.
d. The cerebral hemisphere.
e. The pineal gland.
f. The optic thalamus, on which the pituitary gland is implanted, and which appears only in the side views.
1. Olfactory nerves.
2. Optic nerves.
3. The third pair, or motor nerves of the eye.
4. The fourth pair, or pathetic nerve.
5. The fifth pair, or trifacial nerve.
6. The sixth pair, or abducent nerve.
7. The acoustic nerve.
8. The pneumogastric nerve.
9. The glosso-pharyngeal nerve.
0, 0, 0. Spinal nerves.

367. **Reptiles and Amphibia.**—In reptiles, fig. 285, fig. 286, and fig. 288 ; and in amphibia, fig. 291, the cerebral hemispheres

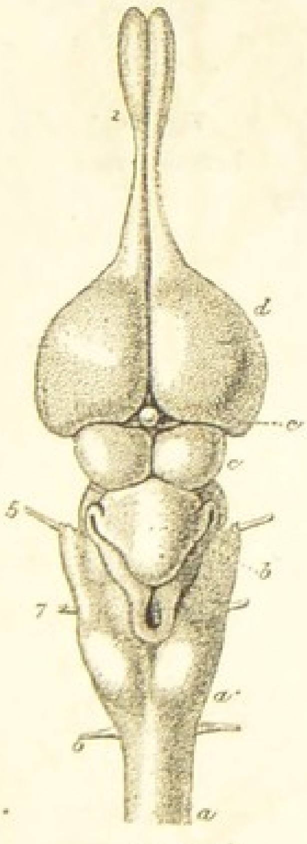


Fig. 285.*
Superior side.

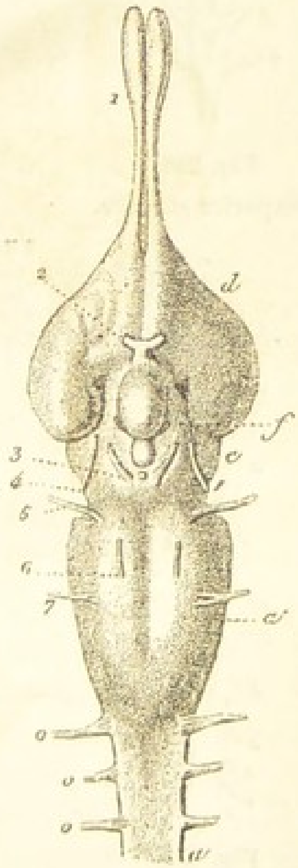


Fig. 286.*
Base.

ENCEPHALON OF THE CROCODILE (Crocodilus lucius).

are still further diminished, and the other parts more completely exposed.

* Cuvier.

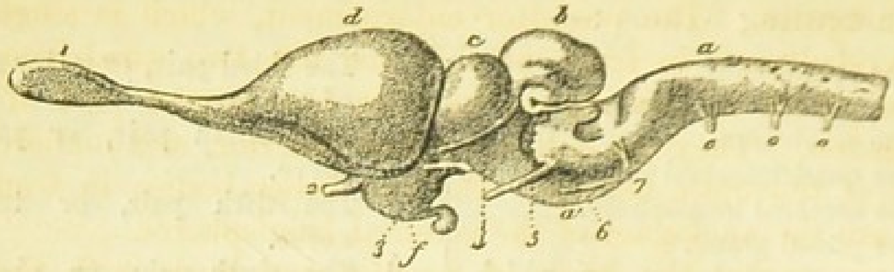


Fig. 287.*
Left side-view.
ENCEPHALON OF CROCODILE (Crocodilus lucius).

Fig. 288.*
Superior surface.

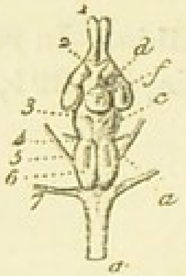


Fig. 289.*
Base.

Fig. 290.*
Left side-view.

THE ADDER (Coluber natrix).

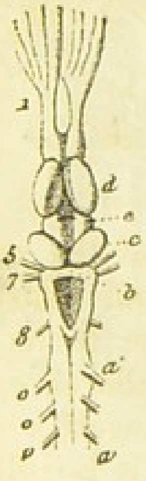


Fig. 291.*
Superior surface.

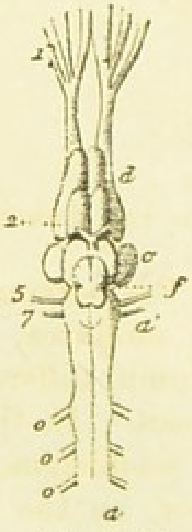


Fig. 292.*
Base.

Fig. 293.*
Left side-view.

ENCEPHALON OF THE COMMON FROG (Rana esculenta).

368. **Fishes.**—The encephalon of fishes, fig. 294, consists of a series of single and double enlargements, the character of

* Cuvier.

which is indicated by the letters and numbers, as in all the former figures. The posterior enlargement, which is single, is the cerebellum: in front of this are the two quadrigeminal bodies, which in this class constitute the largest part of the encephalon. They are hollow in their interior, and include the origin of the optic nerves. The two lesser bodies in front of these are the analogues of the cerebral hemispheres.

In comparing the brain of reptiles and birds with that of mammifers, it is found that the corpus callosum is incompletely formed. The quadrigeminal bodies are hollow, the corpora albicantia are absent, some deep fibres only of the pons Varolii are present; and the lateral parts of the cerebellum are much less developed.

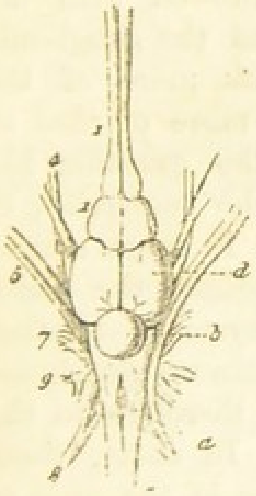


Fig. 294.* Superior surface.

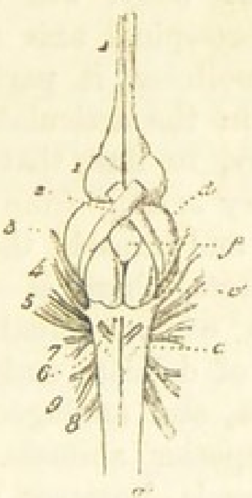


Fig. 295.* Base.

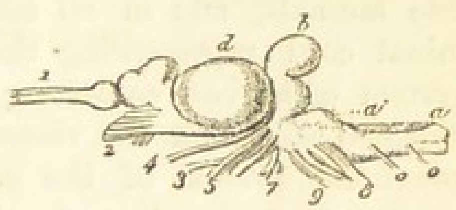


Fig. 296.* Left side-view.

ENCEPHALON OF THE COMMON PERCH.

369. The central part of the nervous system of the various classes of animals, such as mollusca, insects, and crustacea, which have no vertebral column, differs altogether in its form from that of the higher classes. In the latter, the encephalic mass is separated from the œsophagus, lying altogether above or behind it. In the former, on the contrary, it is collected round the œsophagus, forming a ring of nervous matter, which on the dorsal side presents a large ganglion, the analogue of the brain. There is another enlargement, or ganglion, on the lower part of the ring, from which the rest of the nervous system springs: that system consisting generally either of single nervous cords, or of a series of ganglions similar in form and

* Cuvier.

arrangement to those of the great sympathetic nerve in the human organism.

370. **Invertebrata.**—Physiologists have been much divided in opinion as to the character of the nervous system of the invertebrata. Ackermann, Reil, Bichat, and more recently Serres and Desmoullins, considered it to belong to the same class as the sympathetic nerve of the higher animals. On the other hand, Scarpa, Blumenbach, Cuvier, Gall, and J. F. Meckel have rejected all such analogy, and regarded the abdominal cord or chain as representing the spinal cord of the vertebrata. Meckel and P. H. Von Walther considered that the nervous chain of the invertebrata, extending from the brain into the trunk of the body, was endowed with the properties of both the cerebro-spinal axis and the ganglionic system; but that in the mollusca it partook more of the character of the latter, and in the articulata more of that of the former. Müller considers, in fine, that this question has been settled by the discovery arising from the researches of Grant, Newport, Treviranus, and himself, that in most articulate animals, and in all insects, there is—besides the abdominal cord representing the cerebro-spinal system—another system of nerves, consisting of delicate and minute ganglions, destined solely for the viscera, and analogous therefore to the ganglionic system of the superior animals. In short, there appears to be no class of animals, however low in the scale of organisation, in which some traces of a nervous system are not discoverable. Ehrenberg has detected them even in the infusoria, and has distinctly seen them in the rotifera.

371. **Radiata.**—The most simple form of nervous system, the existence of which has been determined in the invertebrata, consists of a mere ring of nervous matter surrounding the œsophagus. In the radiata, fig. 297, this ring is destitute of any ganglionic enlargements. Its ramifications are distributed according to the radiated structure of the animal.

The figure represents the nervous system of the asterias, or starfish; 1, being the feet; 2, the feet cut off transversely; 3, the openings through which the feet projected; and 4, the nervous ring surrounding the mouth, giving off three branches to each ray.

The type of the structure of this class being the repetition of similar organs disposed concentrically, the nerves which issue from the central ring

have a corresponding disposition. These radiating nervous branches, of

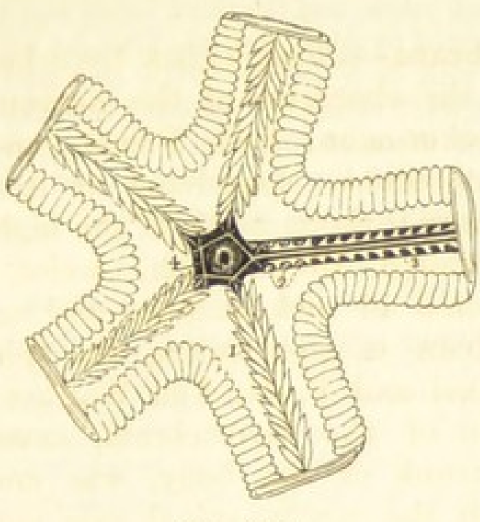


Fig. 297.*

NERVOUS SYSTEM OF THE STARFISH.

which none has more importance than another, constitute collectively the analogue of the cerebro-spinal axis in the higher animals.

372. **Mollusca.**—Ascending from the radiata to the mollusca, a spinal cord, with its ramifications, begins to make its appearance. The body of this class consists of a convolution of viscera, the sensitive and motor functions of which appear to be limited to a dull tactile sense and sluggish power of locomotion. There are, nevertheless, three sets of nerves analogous to the nerves of sensation, those of motion, and the sympathetic nerves of the higher animals. The viscera and locomotive organs having no symmetry of arrangement, no corresponding order prevails in the nervous system, the type of which is a ring surrounding the œsophagus, from which chains of ganglia are given off in different directions, according to the disposition of the organs.

Fig. 297.*

NERVOUS SYSTEM OF THE BLACK SLUG.

* Müller, after Tiedemann.

As an example of this class, fig. 298 represents the nervous system of the common black slug, Limax ater. 1, 2, and 3 represent ganglions, the first above, the second below, and the third before and under the œsophagus. The third are connected by a long delicate filament with the first, and by a transverse filament with each other. They also send branches forward to the mouth and backward along the œsophagus to the stomach. 4, 4, are the optic nerves ; 5, those of the upper lip ; 6, those of the tentacula and the mouth ; 7, those of the respiratory organs ; 8, those of the genital sac, &c. ; and 9, the large nerves of the mouth.

373. **Insects.**—In passing to the insects and articulata in general, the nervous system varies its form, accommodating

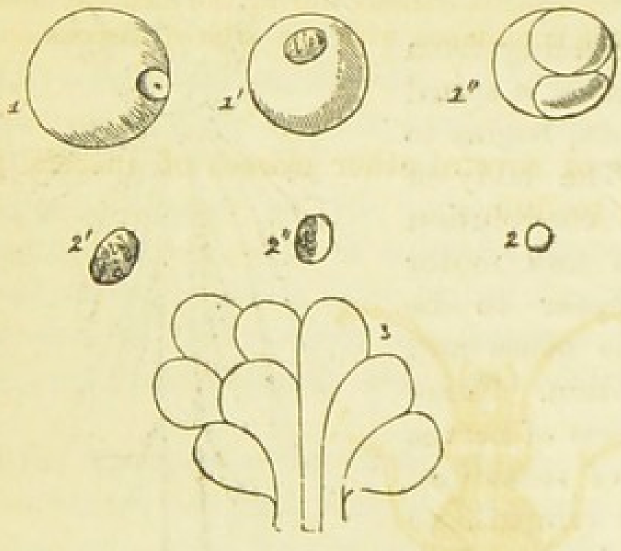


Fig 299.*

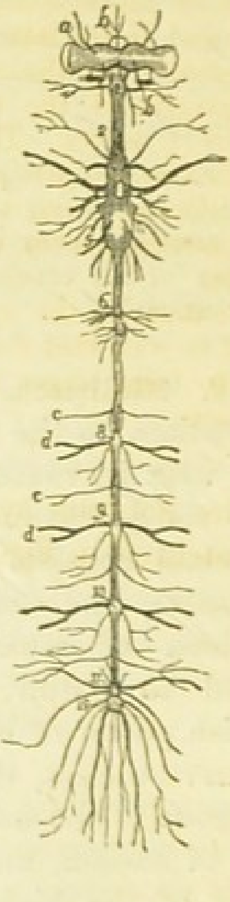


Fig. 300.*

NERVOUS SYSTEM OF THE SPHYNX LIGUSTRI.

itself to the varying form of the structure of the body, and assuming by slow degrees features more and more resembling those of the nervous system of the higher animals. The general character of the articulata consists of a succession of rings similarly organised, jointed together, each ring containing

* After Müller.

similar parts of the vascular system. In accordance with this structure, the ganglions proceeding from the ring of nervous matter surrounding the œsophagus are formed into a chain, each ganglion throwing out corresponding systems of nerves. According to Müller, the brain in all the species of annelides, insects, arachnides, and crustaceans, is above the œsophagus; and in insects, the nervous system of the viscera, corresponding in its functions to the sympathetic nerve, is distinctly developed.

In figs. 299 and 300, the nervous system of the Sphynx ligustri, a species of hawk-moth, is presented; in the former as it exists in the larva, and in the latter as in the perfect insect. The brain, consisting of a ganglion above the œsophagus, is at *a*, and 1, 2, 3 to 12 are the successive ganglia of the abdominal cord, each throwing off laterally like systems of nerves. The median visceral nerve (*b*) arises by two roots from *a*. Two nerves also arise from *a*, on each side forming a small ganglion; these likewise belong to the visceral or sympathetic system. Interganglionic, or transverse nerves, are shown at *c*. *d* are the nerves given off by the ganglia.

In comparing the system of the larva with that of the perfect insect, it will be seen that some of the ganglia coalesce during the metamorphoses, so as to form larger masses in accordance with the altered disposition of the parts.

The nervous systems of several other classes of insects are represented in figs. 301 to 305.

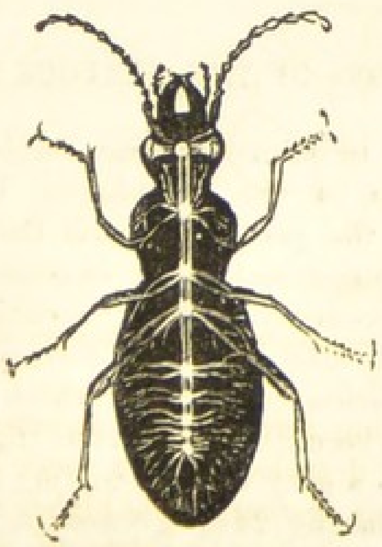


Fig. 301.

A SPECIES OF FIELD BEETLE.

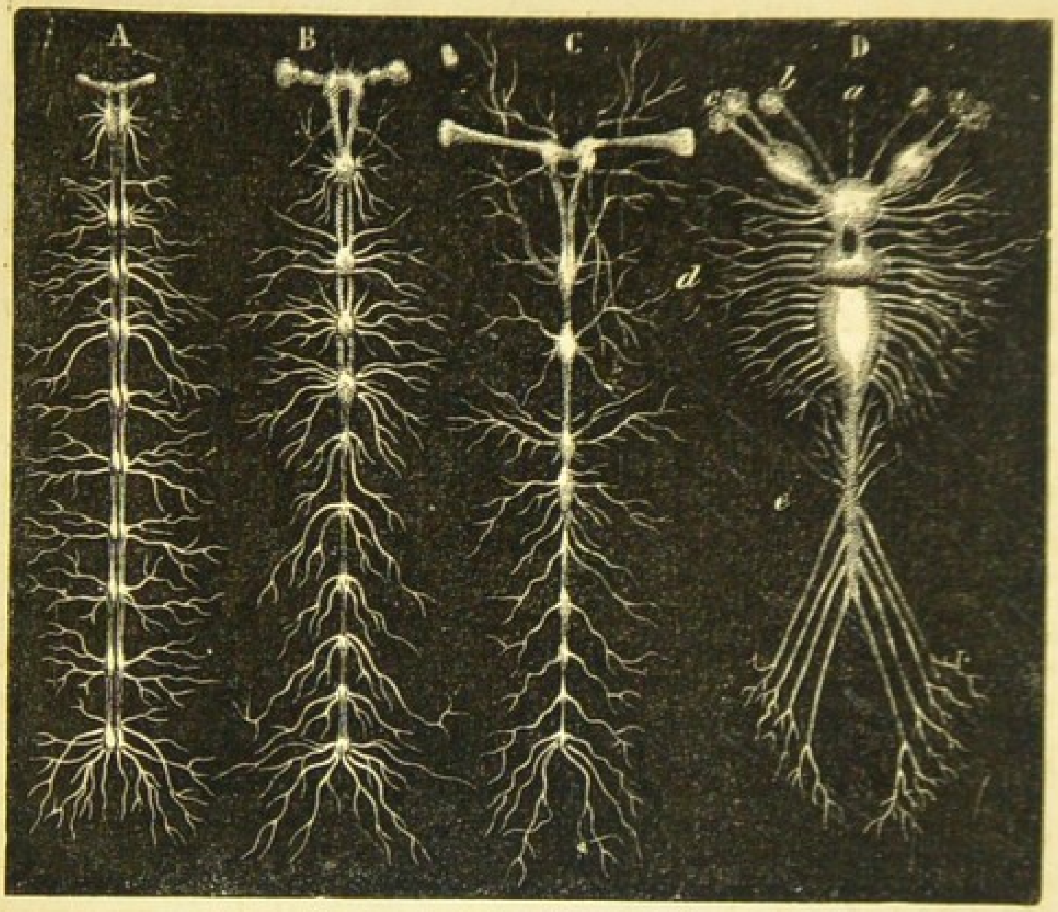


Fig. 302. EARWIG. Fig. 303. GRASSHOPPER. Fig. 304. STAG-BEETLE. Fig. 305. FIELD-BUG.

In the last figure *b* and *c* are the optic nerves, *d* the thoracic, and *e* the abdominal ganglions.

FUNCTIONS OF THE NERVOUS SYSTEM.

374. When the structure of the cerebro-spinal axis, and more especially that of the encephalon, is considered, it is impossible to resist the persuasion that these curiously formed and beautifully symmetrical parts exercise severally distinct influences in the economy. That varieties of structure so remarkable must be attended with corresponding varieties of function, is a proposition the truth of which is all but intuitive. The convoluted and vermiform cerebrum (fig. 244,[19]), consisting of white matter with a grey cortical coating; and the laminated and foliated cerebellum (fig. 244,[17]), consisting of grey matter with some intermixture of white, and exhibiting within that remarkable arborescence already indicated (fig. 240,[4]), must obviously be endowed with different nervous powers. The pons Varolii

(fig. 244,[12]), tied by its crura and peduncles to the cerebrum, the cerebellum and the medulla oblongata, with its white fibres, transverse and longitudinal, interspersed with grey matter,—the quadrigeminal tubercles (fig. 245,[ae]), ranged two on each side of the median plane and one before the other, consisting, contrary to the structure of the cerebrum, of white matter without and grey within, tied by white cords to the cerebellum and the optic thalami,—the corpus callosum (fig. 240,[26]), traversing the longitudinal fissure, and connecting the two cerebral hemispheres,—the medulla oblongata (fig. 244,[13]), with its pyramids and rope-like (restiform) cords, its olive-formed masses (olivary bodies), decussating pyramids, and curiously disposed white and grey matter,—in fine, the multiple spinal cord (figs. 247 to 256), with its fissures and furrows, and its singularly formed pith of grey, surrounded by the larger mass of white fibrous matter—severally present varieties of structure which cannot be admitted to have been contrived and produced without some intelligent purpose.

It might therefore be expected that their respective functions would be assigned to these parts, and connected with them by evidence based upon sufficient induction by the researches of physiologists. Such an investigation, nevertheless, presented difficulties which, until a very recent period, rendered all the labours of experimental inquirers and observers fruitless. In the problems commonly presented to the experimental philosopher, the phenomena to be compared and brought into the relation of cause and effect are all physical, and capable of immediate observation, either when naturally evolved, or when provoked by the express contrivances of the observer. In the present case, however, the phenomena to be compared are mental on the one hand and physical on the other. A physical effect is to be traced to a mental cause, or a mental effect to a physical cause.

The physical effects being organic, and connected with and dependent on vital influences, are extremely difficult of observation; and the mental phenomena with which they stand in relation, much more so. Beset with such difficulties, the extent of the discoveries actually made by physiologists respecting the functions of the nervous system, is a legitimate subject of admiration, although the field which still remains to reward the labours of future observers be still more considerable.

375. **Sensibility.**—The impressions produced by external

physical agents upon the organs are received by the terminal parts of the nervous ramifications diffused through these organs, and by a peculiar property of the nerves they are propagated thence to the seat of perception, which, as will be shown hereafter, is the cerebral hemispheres. This property of the nervous fibres to receive and transmit these impressions is called *sensibility*, and the impressions so transmitted are called *sensations.*

376. **Perceptibility.**—The faculty of the cerebrum to receive the impressions thus transmitted is called *perceptibility*, and the mental consciousness of the impression so received is called *perception.*

377. **Volition.**—But the cerebral hemispheres, as will hereafter appear, are also the seat of *will*, and the nervous fibres are endowed with another faculty, in virtue of which they are susceptible of receiving definite impressions from the mental act of the will, of propagating such impressions to the organ or member indicated by the will, and of imparting to such organ or member, through the agency of the contractile power of the corresponding muscles, the particular motion prescribed by the will.

378. **Excitability.**—This faculty of the nervous fibres, in virtue of which they are susceptible of receiving impressions from the will, and of propagating these impressions to the part indicated, is called *excitability*, and the state of the nervous fibre when so acted upon is called *excitation.*

379. It will presently be demonstrated that the nerves endowed with sensibility are different from, and independent of those endowed with excitability ; the former being distinguished as *nerves of sensation*, and the latter as *nerves of motion.* In general, however, the same nervous cord includes fibres of both kinds, which, though placed in mechanical juxtaposition, have no reciprocal physiological influence whatsoever.

380. **Senses.**—The senses, usually enumerated as five, consist of two classes, *special* and *general.* The special senses are those which are susceptible of impressions only by particular physical agencies, and are those of seeing, hearing, smelling, and tasting—the first being susceptible of no impressions but those of light ; the second, of none but those of sound ; the

third, of none but those of odorous effluvia ; and the fourth only of those produced by the sapid particles of bodies.

381. **Tactile Sense.**—The general sense is that of touch or feeling, called the *tactile sense*, which receives its denomination from its susceptibility of receiving impressions from bodies, in whatever form or state they may exist. By this sense we perceive the qualities of shape, weight, texture, superficial conformation, softness or hardness, and temperature. When any part of the external surface of the organs is brought into contact with a body, we immediately become conscious of the qualities just indicated; we feel that it is smooth or rough, soft or hard, sharp, blunt, or round, and warm or cold. These various impressions are received by the fibres of the nerves of sensation which are diffused over the surface of the organ which is in contact with the object, and they are propagated by these nerves to the cerebrum, where the sensation is perceived.

382. It may be asked, whether impressions so very different as those of temperature and texture are received and propagated to the sensorium by the same nervous fibres ? This is a question to which physiologists have not given a solution. If the different impressions of the tactile sense are received by different nerves, the fact has not yet been ascertained by experiment or observation. The nerves, therefore, of this sense, must for the present be regarded as being susceptible of receiving and transmitting at one and the same moment distinct and independent impressions of all the different physical qualities above mentioned.

383. The functions of the nervous system, so far as they are known, have been ascertained and demonstrated, partly by observations made upon the human subject when placed under the exceptional conditions incidental to disease, to surgical operations, and post-mortem experiments, but chiefly by experiments made upon inferior animals, placed under conditions expressly contrived to provoke such manifestations as might enable the observer to connect, in the relation of cause and effect, the mental and organic phenomena. The result of such researches, combined with the known and admitted analogies of structure and function prevailing between the human and animal organisms, have led to the most important discoveries in the physiology of the nerves.

If the nerve which connects any member of an animal with the cerebro-spinal axis be denuded, as it may be, at any point

of its course, by the dissection of the surrounding parts, and be submitted to mechanical irritation, two effects will immediately ensue : the animal will exhibit unequivocal manifestations of pain ; and the member with which the nerve is connected will be agitated with convulsive motions.

384. In this case, the nervous cord submitted to irritation includes both fibres of sensation and fibres of motion. The irritant applied to the cord acts upon the excitability of one set of fibres and the sensibility of the other. The excitation produced in the fibres of motion descending to the extremities of the nerve, diffused over the muscles of the member, excites their contractility, and produces the convulsive motion. The same irritating agent, acting on the fibres of sensation, excites their sensibility ; and the sensation thus produced is propagated upwards to the cerebrum, where it causes the perception of pain.

In this case, therefore, the irritating agent, applied to the nervous cord, plays at once the part of the will in producing the excitation of the nerves of motion, and of the tactile sense in exciting the nerves of sensation. The excitation of the former descends from the point irritated to the member moved, and the impression on the latter ascends from the same point to the nervous centre.

385. If a ligature be placed on the nervous cord, it will interrupt the propagation both of excitability and sensibility. If, in such case, the nerve be irritated below the ligature, the excitation will descend to the member, and produce, as before, the convulsive motion ; but no pain whatever will be manifested, showing that the transmission of the impression upwards on the nerves of sensation is interrupted by the ligature.

If the nerve be irritated above the ligature, the propagation of the excitation downwards on the nerves of motion will be stopped, as will appear by the absence of all convulsive motion in the member ; but the same manifestation of pain will take place as was exhibited before the ligature was applied.

386. If two ligatures be applied at two distant points of the same nervous cord, and, at the same time, all the ramifications issuing from the cord between the ligatures be cut off, a series of phenomena may be produced which will further illustrate these functions of the tactile and motor nerves. In this case, if the nervous cord be irritated between the ligatures, neither convulsive motions nor pain will be produced, the lower ligature

intercepting the one, and the upper ligature the other. If the upper ligature be then removed, pain will be manifested, but no motion produced. If the lower ligature be removed, maintaining the upper one, convulsive motions will be produced, but no pain manifested.

If both ligatures be removed, convulsive motions will be produced, and pain will be manifested.

If, in fine, after the ligatures have been applied, and before the intermediate ramifications have been cut, irritation be applied beyond the lower ligature, convulsive motions will be produced in those parts to which the ramifications between the lower ligature and the point of irritation extend, but no pain will be manifested.

387. In general, when irritation is applied to any point of a nervous cord without ligatures, convulsive motions will be produced in all the parts to which the ramifications below the irritated point extend, but in none of the parts above it ; and the sensation, which is propagated upwards to the sensorium, will not diverge into the ramifications of the cord placed above the irritated point. The perception of the sensation, in such case, will be the same as if the parts to which the ramifications of the nerves of sensation below the irritated point extend, had been the seat of the pain.

388. The various phenomena above described have been developed in experiments made on the inferior animals, by several physiologists, but more especially, and on a large scale, by M. Flourens. That eminent physiologist, among other experiments to the same effect, denuded the sciatic nerve of a dog by an incision extending from the great trochanter to the ham, and intercepting a part of it between two ligatures, performed all the experiments above described. When the ligature above the point irritated was applied, the animal showed no signs of pain ; but when it was removed, the animal yelled loudly, and struggled to escape. In the same manner, so long as the inferior ligature was maintained, the leg remained immovable, but when it was removed, violent convulsive motions were produced.

Like results were obtained in more than twenty different experiments on different animals.

389. If, instead of applying a ligature as described in the above experiments, the nervous cord be divided at a given point, like effects will ensue. Irritation applied at the stump of the lower branch will produce convulsive motions in the parts

to which the ramifications of the branch extend, provided that the irritation be applied soon after the nervous cord is divided; for, in a certain period after its separation from the cerebro-spinal axis, it will lose its excitability. Irritation applied to the stump of the upper branch will produce the sensation of pain, and the perception of such sensation will be the same as if the seat of pain were the parts to which the ramifications of the lower cord cut off extend. This is a phenomenon familiar to all operating surgeons, and it is a physiological illusion which, in most cases, continues through life. When a limb has been amputated, the stumps of the nerves which ramified through the part cut off maintain their sensibility; and the effect produced upon the individual, thus mutilated, is the same as if he still retained the amputated member, and felt all the sensations in it.

The sensations are most vivid, while the surface of the stump and the divided nerves are the seat of inflammation, and the patient then complains of severe pain felt, as if in the whole limb which has been removed. When the stump is healed, the sensations which we are accustomed to have in a sound limb are still felt; and frequently throughout life there is a tingling, and often pain felt, which are referred to the parts that are lost. These sensations are not of an undefined character; the pains and tingling are distinctly referred to single toes, to the sole of the foot, to the dorsum of the foot, to the skin, &c. It is ridiculous to attribute these important phenomena to the action of the imagination, &c. They have been treated merely as a curiosity; but Müller affirms that he has convinced himself "of their constancy—of their continuance throughout life—although patients become so accustomed to the sensations that they cease to remark them. The sense of tingling or creeping of ants in the hand, foot, or whole extremity, with the same distinctness as when the limb is still present, may be excited much more vividly by applying a ligature or tourniquet to the stump, or by exerting pressure on its nerve; hence, patients have the feeling of their lost limb most distinctly, when from any cause the application of the tourniquet is again necessary. If the patient have suffered before amputation from a local painful affection of the limb, the whole limb will still be felt as if in pain after its removal; and pain is felt as if in the whole limb, at the moment when the nerve is divided, and during the inflammation of the stump."*

* Müller's Physiology, vol. i. p. 694.

390. **Effects of Mechanical Irritation.**—Müller gives the following examples of the continuance of this transfer of sensations produced by irritation of the stumps of the nerves to the corresponding parts of the lost member :—

Wolff, a tailor in Bonn, whose leg had been amputated above the knee, complained, on the following day, of pains in the toes of the amputated leg. At the end of twelve years he had still feelings, and, occasionally, severe pains in the toes and sole of the lost foot. He sometimes had the sensation which is popularly described as that of the foot being asleep. On applying a tourniquet to the stump, so as to press upon the ischiadic nerve, he felt his lost leg asleep, and had a distinct tingling in the toes.

Schmidt, a student from Aix, who had his arm amputated above the elbow, felt sensations in the lost fingers thirteen years afterwards. Pressure on the nerves gave him, as in the former case, the sensation of the hand being asleep.

A toll-keeper near Halle, who had served in the army, had his right arm shattered by a cannon-ball, above the elbow, in 1803. The arm was amputated, and, twenty years afterwards, he suffered from rheumatism in it which returned with all changes of weather. The rheumatic pains were distinctly felt in all parts of the lost arm, which was constantly sensible to the effects of draughts of cold air. This man never lost the sense of the integrity of the amputated limb.

391. **Effects of Galvanism.**—Mechanical irritation may be replaced by other irritants, such as chemical stimuli, extremes of heat and cold, and electricity.

If one of the poles of a galvanic battery be applied at any point of a denuded nerve, the other being applied to a part in which the ramifications of the same nerve are diffused, convulsive motions and a sensation of the electric shock will be manifested. It has been maintained by some, that the agency to which this physiological phenomenon is due is the electric fluid transmitted along the nerve to the muscle ; that this is not the case, however, may be easily demonstrated.

Let the two poles of the battery be applied to any two points of the denuded nerve, so that the electric current shall only pass along that part of the nerve which is intercepted between the poles, the convulsive effects of the shock and the same sensation will be manifested. If a ligature be applied between the poles, it will stop the transmission of the physiological impression along the nerves, as well of motion as of sensation ; but it will not interrupt the electric current.

In that case, both the convulsive motion and the sensation due to the electric discharge will be manifested, but they will be produced after a different manner ; the convulsive motion being caused by the impression made on that part of the nerve only which is below the ligature, and the sensation of the shock by that part of it which is above the ligature. This may be demonstrated by applying a second ligature first above the upper pole and then below the lower one. A ligature placed above the upper

pole will intercept the sensation and prevent the shock from being felt, but the convulsive motion will be still produced. The ligature placed below the lower pole will intercept the excitation and prevent the production of the convulsive motion, but the sensation of the shock will still be maintained.

These phenomena were developed in numerous experiments made by Humboldt, Pfaff, Marianini, Ermann, and others.

392. It appears generally from what has been here stated, that irritation of a nerve of motion produces convulsive motions in the part in which the nerve terminates, provided that the connection of the irritated point with the extremity of the nerve be uninterrupted, and that the irritation of a nerve of sensation produces pain, provided that the connection of the irritated point with the brain be uninterrupted; and this is true, whatever be the nature of the stimulus by which the irritation is produced. Excitability is, therefore, always propagated downwards, and sensibility upwards.

393. **Irritation of Spinal Nerves.**—The effects which have been noticed in the experiments related above are all produced on nerves of general sensibility, and are consequently all either feelings of pain or sensations of touch. The same experiments applied to the nerves of special sensibility are not so easily made ; nevertheless, under certain conditions effects are produced which prove that the latter nerves are subject to laws similar to those of general sensation here demonstrated. Magendie showed, that while the optic nerves, irritated as they may be, by the effect of pressure or by a blow on the eye, produce the sensation of a flash of light, they are altogether insensible to pain, and have consequently no tactile sensibility. In the same manner, mechanical irritation of the auditory nerve produced by the jarring of the head and ear in long journeys produces a sensation of sound. In certain maladies, the same nerve being excited by internal causes, singing and buzzing of the ears is felt. This nerve, like the retina, is altogether exempt from tactile sensibility.

If a metallic plate, connected with one pole of a voltaic battery, be applied to the end of the tongue, and another wetted with salted water, and connected with the other pole, be applied to any part of the face, the metal on the tongue will excite a peculiar taste, acid or alkaline, according as it is connected with the positive or negative pole.

If a metallic plate, wetted with salted or acidulated water, be applied at or near the eyelids, and another be applied at any other part of the person, a peculiar flash or luminous appearance will be perceived the moment the

plates are put into connection with the poles of a battery. The sensation will be reproduced, but with less intensity, the moment the connection is broken. A like effect, but less intense, is produced, when the current is transmitted through the cheek and gums.

If the wires connected with the poles of a battery be placed in contact with the interior of the two ears, a slight shock will be felt in the head at the moment when the connection is made or broken, and a roaring sound will be heard so long as the connection is maintained.

394. **Properties of Spinal Cord.**—Exclusive of other important functional properties, the spinal cord has those which it derives from being the conductor of nervous influence between all the spinal nerves and the brain. Whether all the fibres of these nerves which enter the cord at the points where they are severally implanted, are continued upwards through the interior of the cord to the brain, or whether the nervous influence is imparted by the nervous fibres to the constituent matter of the cord, and by it propagated to the brain, their functional properties and their consequences will be the same. The spinal cord will be still the medium, and the only one, by which the nerves and the brain are placed in communication. Any interruption, therefore, produced in this line of communication, must on the one hand intercept the transmission of sensation from the various internal organs and the limbs to the brain, and on the other hand, the transmission of motion from the brain to the organs and members.

The first physiological point to be determined, then, relates to the localisation of the fibres of sensation and those of motion. These fibres are in general mechanically combined in the nervous cords, where, however, they are physiologically independent. Does the same mechanical combination continue throughout the spinal cord ?

395. Nothing can be more clear and conclusive than the experiments first made by Sir Charles Bell, and afterwards repeated and varied by other eminent physiologists, among whom may be named Magendie, Longet, and Flourens, in France, and Müller in Germany, by which this point was determined. Without reproducing the numerous details of such experimental researches, we shall here state their principle and results.

Let the spinal cord be supposed to be denuded between any two points of its length and stripped of its investing membranes, so as to lay bare the roots of the spinal nerves. If the anterior root of any nerve so exposed be then irritated, convulsions will be produced in the member or organ to which such nerve passes, but no pain will be manifested. If a similar

irritation be produced on the posterior root, pain will be felt and manifested, but no motions produced, and the same will take place, without exception, in the case of all the spinal nerves.

396. It follows, therefore, that when the nervous cords divide on approaching their apparent roots in the spinal cord into two branches, anterior and posterior, the fibres which thus separate are endowed with different physiological functions; those which diverge into the anterior root being the motor, and those of the posterior root being the sensitive fibres. At the point of divergence, the trunk of the nerve is physiologically decomposed.

This conclusion is further corroborated by the effects produced by the division of one or other root. If the anterior root be cut, the member or organ to which that nerve passes will be paralysed, but its sensibility will be maintained. If the posterior root be similarly divided, the power of voluntary motion of the corresponding parts will be maintained, but their sensibility destroyed. In the one case the parts will be removed from the dominion of the will by the division of the motor fibres; in the other, the propagation of sensibility to the brain will be interrupted by the cutting through of the sensitive fibres. In fine, if both anterior and posterior roots be divided, the corresponding parts will be at once paralysed and rendered insensible.

397. It will be recollected that the spinal cord consists of four parts, two lying on each side of the median plane (*a p*, figs. 306 and 307). Each of these lateral divisions of the cord is again divided into two parts—an anterior and a posterior—by a line of gray matter. In the figures, *a b* is

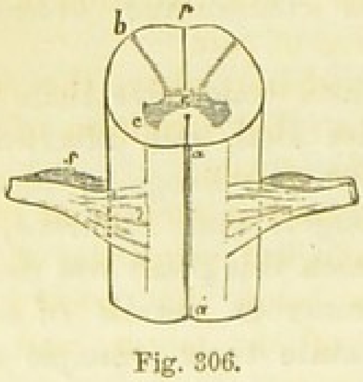


Fig. 306.

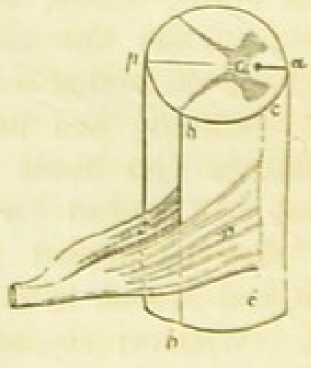


Fig. 307.

the right anterior part of the cord, and *b p* the right posterior part; the left anterior and left posterior holding corresponding positions on the other side, and being separated from the former by the anterior and posterior median fissures already described (page 259). The anterior roots of the spinal nerves, as already explained, on each side are implanted in the anterior, and the posterior roots in the posterior part of the cord.

398. This being understood, we shall proceed to explain some of the principal functional properties of the spinal cord, as they have been developed in the experimental researches of M. Flourens, and confirmed in their most essential points by those of other physiologists.

Since the anterior roots of the nerves are implanted in the anterior, and the posterior roots in the posterior parts of the cord, it might be inferred, *à priori*, that their respective fibres would be continued, the former along the anterior, and the latter along the posterior divisions, and that consequently the cord would be endowed with the same properties of excitability and sensibility as the roots of the nerves are proved to possess, and that the seat of the excitability would be in the anterior part of the cord, and that of the sensibility in the posterior part.

The results of the experiments of M. Flourens upon various individuals of the lower species are in complete accordance with this. Irritation applied to the posterior part always produced decided manifestations of pain, but no convulsive movements. Irritation applied to the anterior part, on the contrary, produced convulsive movements, but no manifestations of pain.

The division of the cord at any point of its length produced at once the paralysis and insensibility of all the parts supplied with nerves having their roots below the point cut through; but neither paralysis nor insensibility affected the parts receiving nerves above that point.

Irritation of the anterior part of the cord below the point of section produced convulsive motions in all the parts receiving nerves from the spine below that point; but irritation of the posterior part produced no manifestation of pain.

Irritation of the anterior part immediately above the point cut through produced no convulsions; but irritation of the inferior part produced unequivocal signs of pain.

It follows, therefore, that the spinal cord at each point of its length is endowed with all the physiological properties of the spinal nerves which have their roots below that point; the anterior part having the properties of the motor, and the posterior part those of the sensitive nerves.

399. Numerous phenomena developed in pathology, and manifested in surgical practice, are in accordance with these results. Thus, lesion of the lowest parts of the cord produces paralysis of the inferior extremities, of the rectum and bladder. If the lesion be situated higher, the abdominal

muscles are also paralysed; if still higher, paralysis of the thoracic muscles is added. The lesion of the cervical division of the cord below the origin of the fourth cervical nerve paralyses, in addition to all the parts above mentioned, the arms, but the diaphragm escapes, the fourth cervical being untouched. In fine, the lesion of the medulla oblongata, through which the communication of all the nerves of the trunk with the brain takes place, paralyses the whole trunk.

When the lesion of the spinal cord is propagated gradually from below upwards, as in the malady called *tabes dorsalis*, the paralysis of the body is produced in the same manner gradually upwards.

The cord thus possesses all the functional properties which would attach to it as the common trunk of all the nerves of the body. If a galvanic shock be applied to the summit of the cord, all the muscles of the trunk and members will be thrown into convulsions.

400. The nervous influence propagated by the spinal cord between the brain and the members and organs of the body, is not merely collective, as if the matter composing the cord possessed the propagating power as a common property; for it is found that different parts of the cord interrupt the transmission of nervous influence between the brain and particular muscles only of the trunk. The lesion of certain parts paralyses particular members or organs of the body alone; lesion affecting one side of the brain and spinal cord, produces paralysis of one side only of the trunk. The less extensive the lesion of the spinal cord, the smaller will be the number of parts deprived of voluntary motion or rendered insensible. If it be considered, as will be explained more fully hereafter, that the number and intensity of the muscular contractions which produce such voluntary motion are regulated by the action of the cerebrum, it will follow, as a necessary consequence, that the primitive fibres of the nerves in passing along the cord do not unite with each other, but continue their course separately and independently, the sensitive fibres communicating to the brain independent sensations, and the motor fibres transmitting from the brain independent motions. The supposition that the nervous fibres coalesce in the cord, or that the matter of the cord itself should be a common medium of communication, would be altogether incompatible with such an isolated and independent transmission of sensation and excitation.

"We may, therefore," says Müller,* "regard the spinal cord as a trunk formed of nervous fibres, which sends out anteriorly and posteriorly, in uninterrupted series (figs. 254, 5, 6), many millions of primitive fibres, of motor and sensitive endowment, to all parts of the body ; these fibres being, between their origin and peripheral termination, collected into numerous large and small fasciculi by means of cellular sheaths."

401. Physiologists, nevertheless, are not in complete accordance as to the parts of the spinal cord through which the sensitive and motor nerves respectively and exclusively pass. If the cord could be partially divided without compromising the parts not divided, this problem might be satisfactorily solved by experiment ; but in dividing the posterior columns, the anterior ones are unavoidably submitted to pressure ; besides which, it is the opinion of eminent anatomists that the two columns anterior and posterior have not been shown to be anatomically distinct. Although, therefore, the prevalent opinion of physiologists is in accordance with the results explained above, some maintain that the posterior part of the spinal cord has a certain motor influence, while others pretend that the region of the motor fibres is the white matter, and that of the sensitive fibres the gray matter, of the cord.

402. **Reflex Nervous Action.**—Another cause of uncertainty attending experiments made on the anterior and posterior columns of the cord, is a power with which the cord is endowed of reflecting the impressions of sensitive fibres upon the motor fibres; so that even supposing, as contended by Flourens and the greater number of physiologists, that the anterior columns are exclusively motor, and the posterior sensitive, any injury or cause of irritation to the posterior columns would be liable by reflection to affect the anterior columns, so as to produce convulsions in the corresponding members; and in such case the motor character would be erroneously ascribed to posterior columns.

It is remarkable that this property of lateral nervous reflection from the sensitive to the motor fibres with which they are in juxtaposition, which undoubtedly takes place within the spinal cord, does not at all exist between the sensitive and motor fibres, which are packed within the same neurilemma of a nervous cord. This may be explained, however, by the fact

* Physiology, transl. p. 798.

that such fibres in the nervous cord are, as already explained, enclosed within independent sheaths, composed of matter which is a non-conductor of the nervous influence, while the fibres which pass along the columns of the spinal cord, are not invested with such sheaths.

403. **Limits of Sensibility.**—The general excitability and sensibility of the spinal cord being established, the question to determine the limits of the play of these properties arises. If the entire extent of the cord and the surface of the encephalon be denuded and submitted to experimental irritation, it will be found that the convulsive movements will be produced, and pain will be manifested if the point of irritation be transferred gradually upwards to the medulla oblongata (fig. 244, [13]), and beyond that part to the peduncles (figs. 239*a* and 244) of the brain. Beyond this, neither excitability nor sensibility will be manifested. No movements will ensue, nor will any indications of pain be shown. Here, then, would be the limit of excitability and sensibility.

As a counterproof, let the irritation commence with the encephalon and be gradually continued downwards. No convulsions nor signs of pain will attend the irritation or laceration of the cerebrum (fig. 244, [20]), the cerebellum (fig. 244, [17]), or the corpus callosum (fig. 240, [26]). This was fully proved, relative to the first two, by the experiments of Haller and Zinn, and relative to the last by Lorry. Some physiologists affirmed that they had excited convulsive movements by puncturing the corpus callosum, but M. Flourens, with his characteristic clear-sightedness, has shown that in these cases the puncture had penetrated to the cerebral tubercles, of which the lesion produced the movements.

M. Flourens, pushing further the researches of Haller, Zinn, and Lorry, showed that the same absence of excitability and sensibility characterised the corpora striata (fig. 242, [12]) and the optic thalami (fig. 245,[11]), and that the received doctrine that the lesion of the latter parts produces paralysis of the iris is erroneous; for that however the thalami may be pricked, lanced, or cut, the iris maintains all its contractibility and other functions unimpaired.

404. Haller and Zinn found that the puncture and lesion of the cerebellum produced convulsive motions, an error corrected by Lorry and Flourens; the latter of whom showed that the convulsions arose from the puncture or lesion, in the experi-

ments of Haller and Zinn, having penetrated to part of the medulla oblongata lying beneath the cerebellum.

Carrying the point of irritation to the quadrigeminal tubercles in mammifers, no signs of excitability are yet produced, but in birds, the corresponding bigeminal tubercles being irritated, contractions of the iris ensue. The irritation being transferred to the medulla oblongata, decided convulsive movements are produced in all classes.

405. These points at which the excitability begins to appear in carrying the irritation downwards are precisely those at which it ceases in carrying it upwards. It is, therefore, clearly the limit which separates the excitable from the unexcitable regions of the cerebro-spinal axis, and it lies a little higher in birds, extending to the bigeminal tubercles, than in mammifers, in which it is placed at the summit of the medulla oblongata.

This remarkable functional difference between these two regions of the cerebro-spinal axis is, as might be expected, concomitant with an equally remarkable structural difference. In the cerebrum, and other parts unexcitable, the superficial matter is everywhere gray, while in the medulla, cord, and all the excitable parts, it is white.

406. This difference of substance is not the only distinguishing character of these two regions. The excitable region is that in which the nerves are exclusively implanted. No nerve arises directly either from the cerebral hemispheres, the cerebellum, or any other of the unexcitable parts of the encephalon. The connection of these parts with the nervous ramifications is only that which is supplied by the peduncles which unite them with the medulla oblongata and the summit of the spinal cord.

By reference to the view of the base of the encephalon (fig. 244), it will be seen that most of the cranial nerves have their origin in the medulla oblongata and adjacent parts of the superior extremity of the cord.

407. **Action of Electricity on Spinal Cord.**—Like the nerves, the spinal cord and medulla are susceptible of excitation not only by mechanical irritation but by other stimuli, and especially by electricity. If a voltaic current be transmitted between any two points of the cord, the same effects will be produced as when it is transmitted between two points of a nerve, but the convulsions are much more general, inasmuch as they extend to all the parts which receive nerves from the division

of the spine which lies below the point of application of the higher pole.

Such experiments made upon bodies recently deprived of life have been attended with remarkable effects, all of which, however, are easily explicable on the principles which have been here established.

Galvani's original experiment, and its accidental origin, are well known. It happened that several frogs, prepared for cooking, lay upon the table of his laboratory, near to which his assistant was occupied with an electrical machine. On taking sparks from time to time from the conductor, the limbs of the frogs were affected with convulsive movements resembling vital action.

This was the effect of the inductive action of the electricity of the conductor upon the highly electroscopic organs of the frogs; but Galvani was not sufficiently conversant with this branch of physics to comprehend it, and consequently regarded it as a new phenomenon. He proceeded to submit the limbs of frogs to a course of experiments, with the view to ascertain the cause of what appeared to him so strange. For this purpose, he dissected several frogs, separating the legs, thighs, and lower part of the spinal column from the remainder, so as to lay bare the lumbar nerves. He then passed *copper* hooks through that part of the dorsal column which remained above the junction of the thighs, without any scientific object, but merely for the convenience of suspending them until required for experiment. It chanced, also, that he suspended these *copper* hooks upon the *iron* bar of the balcony of his window, when, to his inexpressible astonishment, he found that whenever the wind or any other accidental cause brought the muscles of the leg into contact with the iron bar, the limbs were affected by convulsive movements similar to those produced by the sparks taken from the conductor of the electric machine.

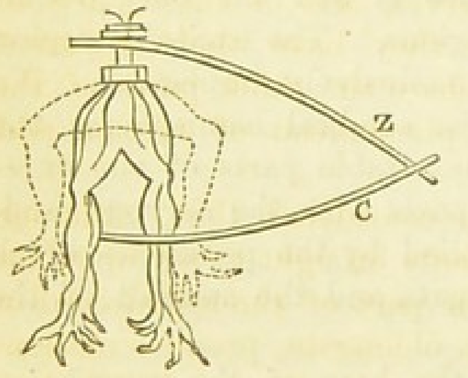


Fig. 308.

This fact, reproduced and generalised, supplied the foundation of the theory of animal electricity propounded by Galvani, and for a considerable time universally accepted. In this theory it was assumed that in the animal economy there exists a specific source of electricity; that at the junction of the nerves and muscles this electricity is decomposed, the positive fluid passing to the nerve, and the negative to the muscle; and that, consequently, the nerve and muscle are in a state of relative electrical tension, analogous to that of the internal and external coatings of a charged Leyden jar. When, under these circumstances, rods of metal (z c, fig. 308) are applied, one to the nerve, and the other to the muscle, the opposite electricities rush towards each other along the conducting rods; a discharge of the nerve and muscle takes place, like that of the Leyden jar; and this momentary derangement of the electrical condition of the organ produces the convulsive movement.

Experiments of this kind have since been made with still

more striking results on inferior animals, and also on the human subject.

The current sent through the claw of a lobster recently torn from the body, will cause its instant contraction.

If a silver coin be laid upon a sheet of amalgamated zinc, a leech placed upon the coin will betray no sense of a shock until, by moving, some part of it comes into contact with the zinc. The connection being thus established, the leech will receive a shock, as will be rendered manifest by the sudden recoil of the part which first touches the zinc.

Among the experiments of this kind made on the human subject, the most remarkable have been those of Dr. Ure. In one of these he applied one of the poles of the pile to the supra-orbital nerve, and the other to the nerve of the heel of a convict recently executed. On completing the circuit the muscles are described to have been moved with a fearful activity, so that rage, anguish, and despair, with horrid smiles, were successively expressed by the countenance, with a revolting resemblance to vitality.

Having denuded the spinal cord and the sciatic nerve, he applied to them the poles of a battery of 270 pairs, when the entire trunk underwent a violent shuddering. By varying the points of application of the poles, the movements of laboured respiration were produced, the abdomen and chest rising and falling, accompanied by frightful grimaces.

408. **Functions of the Brain.**—Having thus explained the functions and properties of the nerves, and of those parts of the cerebro-spinal axis in which they have their apparent origin, it remains to inquire what share the other parts of the cerebral organisation have in the phenomena of motion and sensation.

In the first place, it must be considered that, although mechanical and other physical irritants brought to act upon the nerves of motion or on the anterior part of the spinal cord or corresponding parts of the medulla oblongata, produce motions in the parts to which the corresponding nerves are distributed, such motions are generally convulsive and irregular, and that by no stimuli can the normal motions which characterise the action of the body when the will acts on the system in its state of integrity be reproduced. There is, therefore, a power resident in the organism independent of that which merely excites the nerves, by which the force imparted to the various nervous fibres is so regulated as to produce the motions or actions dictated by the will. The motions of the limbs are not the effects of single muscular actions, but the resultants of a diversity of mechanical forces imparted to the muscular fibres by the nerves. To accommodate these component forces one to another, both in respect to their intensity and direction, so as

to give to their resultant the exact direction and intensity which is prescribed by the will, would be a mathematical and mechanical problem of some difficulty; yet this problem is solved by some intuitive principle established in the organism; for we find not only children, but the inferior animals, as completely masters of their movements as the most profound mathematicians could be. The will, then, is the faculty which prescribes a bodily act, but there is another faculty whose function is to regulate the various nervous forces by which this act can be performed, and this function is instinctive, intuitive, and, apparently, involuntary.

Again, sensibility has been defined to be the susceptibility of the organs to receive the impressions from external objects, and to transmit them to the sensorium, or seat of consciousness and thought; and it has been demonstrated that this sensibility is a function of the nerves, the spinal cord, and the medulla oblongata, which is its continuation, but that at the summit of the medulla it terminates, and does not appertain to the other parts of the encephalon. Since it cannot be doubted that the other parts are the seat of thought, will, and perception, it follows that these faculties are assigned to organs wholly different from those to which the functions of excitability and sensibility have been assigned.

In his experiments on inferior animals, made with the view of determining the functions of the unexcitable and insensible regions of the encephalon, M. Flourens, having denuded the cerebral lobes, removed all the matter of which they consist, taking care to derange or disturb no other parts. The wounds produced in this operation being allowed to heal and cicatrise, and care being taken in the treatment of the animal, its physical health was completely re-established, and in some cases it was even fattened.

It was evident, therefore, under such conditions, that whatever faculties the animal might be ascertained to have lost, must be precisely those of which the cerebral lobes are the seat.

409. **Brain the Seat of Will and Sensation.**—The faculties of which the animal is, in such case, found to be deprived, are those of perception and will, and, as a necessary consequence, of thought and all its modifications. Meanwhile all the organs of sense and organic life are preserved in their integrity. The iris expands and contracts as the intensity of the light to which it is exposed is decreased or augmented; the visual pictures

are produced upon the retina, and the optic nerves are impressed, and their impressions propagated to the quadrigeminal tubercles with which these nerves are connected; but here the effects cease. There is no perception of the visible object. The organs of sight discharge their duty, but there is no consciousness of the impression they transmit; and, with the organs of vision unimpaired, there is, nevertheless, blindness the most absolute.

The same may be said of the other organs of special sensibility—hearing, tasting, and smelling—of none of which there is the least perception.

410. But most wonderful of all, the tactile sense is equally incapable of exciting perception. The animal will knock itself against any obstacle which may be in its way, and be wholly unconscious of the shock.

The animal thus mutilated will be totally incapable of all voluntary motion, although the organs of locomotion are unimpaired. It may move, but if it do, the movement will proceed from external excitement, and the will can have no share in it.

411. **The Brain the Seat of the Mind.**—These conclusions, which have been founded upon extensive series of experiments on inferior animals, giving results in general accordance, establish the physiological principle that the organ of mind resides in the cerebral hemispheres. By the division of the nerves or of the spinal cord, the brain loses none of its powers, no effect being produced by such mutilation, except that the region of its influence is diminished, and the number of parts over which its power extends is decreased; but the intellectual faculties are no more affected by the separation of these parts of the cerebro-spinal system from the encephalon, than they would be by the amputation of a limb.

412. Numerous analogies and physiological phenomena further confirm this conclusion, that the brain is the seat of the mind. If no part of the vertebral cord, or medulla oblongata, be the seat of intelligence, still less can that principle reside in any other part of the system. Members, as Müller justly observes, may be amputated, and organs gangrened, but the mind retains its lucidity while life continues. Delirium, it is true, occasionally attends visceral inflammation; but it may equally arise from the cutaneous inflammation of the extremity of a member; yet the entire limb, skin and all, may be detached

from the body without the least loss of mental power. In this way it may be shown that none of the viscera of the abdomen can be the seat of intelligence. The whole texture of the lungs is sometimes destroyed in chronic maladies, the intellectual faculties being, meanwhile, maintained in all their perfection; and except so far as the local circulation of the brain may be disturbed, the mental powers remain altogether unimpaired by diseases of the heart.

413. But, on the contrary, every cause which deranges the brain, properly so called, immediately disturbs the powers of intelligence. Inflammation of that organ is ever accompanied by delirium, and subsequently by stupor. Pressure upon it, from whatever cause it may arise, external or internal, is attended with the same effects. The same causes, according to the seat of their action, often extinguish will and memory; but when their action is suspended, the will resumes its power, and memory returns. In such cases it has been observed that, at the moment of restoration, the chain of thought is resumed precisely at the point at which it was interrupted by the injury. In lunatics, structural cerebral changes generally take place, although, with our imperfect means of investigation, and defective knowledge, they cannot always be detected in the microscopic texture of the cerebrum. It has been objected to the proposition, that the brain is the exclusive seat of the mind, that very considerable disease may affect that organ, while the mental faculties remain unimpaired. Experiments, however, of physiologists, and more especially some of those made by M. Flourens, to be presently noticed, supply an answer to this.

414. Many distinguished writers, for example, Bichat and Nasse, although they admit that the brain is the seat of the higher intellectual faculties, still maintain that other organs also, as the abdominal and thoracic viscera, have a certain connection with the mental functions, and incline to the belief that the source of the passions may possibly be in these organs. They form their opinion partly on the circumstance of the viscera of the chest and abdomen being affected during the prevalence of passions of the mind, and partly on their being frequently diseased in cases of insanity. It is certain that the intestinal canal, liver, spleen, lungs, and heart, are frequently the seat of disease in lunatics, and occasionally even when no palpable change can be detected in the brain itself; and here the diseases of the abdominal or thoracic viscera may have been the exciting cause of the mental affection, but only in the same

way as other causes might excite it, by the impression communicated to the brain; there being in it some pre-existing disposition to morbid action, either hereditary or acquired. Hence, in these patients, by removing the morbid change in the other viscera which has influenced the brain, the disposition in the latter organ to abnormal action may be reduced again to a latent state.*

415. **Organic Division of Labour.**—Assuming, then, the cerebral lobes, or brain properly so called, to be the exclusive seat of intelligence, there is, as M. Flourens has shown in his researches, a complete division of labour in the apparatus of sensibility. The parts which are directly affected by external objects cannot themselves perceive the impressions made upon them; and, on the contrary, the part which perceives these impressions, if it were acted on directly by the objects, would be completely insensible to them. The cerebral lobes, by which we perceive the impressions of light upon the eye, would be completely insensible to the impression of light transmitted directly upon them; and the eye, though retaining all its organic perfection and susceptibility, is incapable of any perception of light when the cerebral lobes were removed.

There are thus, in organic sensibility, three distinct powers, whose co-operation is necessary. *First*, the power of receiving from external agents such an impression as can produce a sensation. This is the function of the organ of sense. *Secondly*, the faculty of transmitting such impressions from the organ on which they are produced, to the seat of perception. This is the function of the nerves, the spinal cord, and the medulla oblongata. And *thirdly*, the faculty of perceiving or being conscious of the sensation thus produced. This, in fine, is the function of the cerebral lobes.

416. **Flourens' Experiments.**—Our limits preclude us from quoting at length the experiments on which these important physiological conclusions are based. We must refer the reader for their details to the admirable series of researches which appear in the Memoirs of the Academy of Sciences, from 1822 to 1828.†

* Müller's Physiology, transl., vol. i., p. 817.

† These Memoirs, with Cuvier's report, have been published in a separate volume with the title "Recherches Expérimentales sur les propriétés et les fonctions du Système Nerveux dans les Animaux vertébrés, par P. Flourens; Paris, 1842."

We shall nevertheless give one or two examples, selected from those published by M. Flourens, illustrating the principles he has established, which have been confirmed by subsequent experiments and observations made by other eminent physiologists.

The cerebral lobes were removed from a strong and vigorous fowl, which survived for ten months in perfect health, but completely deprived of all perception and will. Its organs of sense remained perfect, but it neither saw, heard, smelled, tasted, or felt. It manifested no sign of volition. It stood nevertheless steadily upon its legs, walked when it was irritated or pushed, flew when it was thrown into the air, and swallowed food and drink when they were put into the opening of its throat. It never stirred voluntarily. If it were placed upon its feet, it remained so. If it were placed sitting in the position of fowls, while in sleep or repose, it would remain in that position. It was in a state of constant stupefaction, sensible neither to noise nor light. The animal being carefully fed, it enjoyed perfect health, and was even fattened. It slept much, but when awake was always in a state of stupefaction. It never took food voluntarily. When its head was forced into grain or water, it made no attempt to eat or to drink, but remained immovable, with its head plunged in the one or the other. It showed no sense of taste or smell, and would as readily swallow small pebbles as grains of corn. If, when forced to walk, it encountered an obstacle, it would strike against it, and appear insensible to the obstruction.

"In fine," concludes M. Flourens, "this brainless fowl had lost all its senses. It neither saw, nor heard, nor smelled, nor tasted, nor felt. It lost even its instincts; for, however long it was left to fast, it never voluntarily ate; it never shrunk from any severities to which it was exposed; when attacked by its fellows, it made no attempt at self defence, neither resisting nor escaping; the male had no attraction for it, of the union with whom it was wholly unconscious. It lost every trace of intelligence, for it neither willed, remembered, or judged.

"It follows, therefore, that the cerebral lobes of which this animal was deprived, are the seat of perception, instinct, will, and intelligence."

417. The seat of perception, will, and intelligence, being thus traced to the cerebral lobes, another point remained to be established. Is the seat of these faculties a particular point in the cerebral lobes? Is will exercised by one part, and perception by another; or is the exercise of both these faculties limited to particular convolutions, or particular points of the cerebral hemispheres?

To determine this, M. Flourens removed gradually the cerebral matter of the lobes, observing the effect produced after each removal, time being allowed for the proper subsidence of the tumefaction produced by the lesion. He found, accordingly, that the faculties appertained to no particular part of the lobes more than to another, and that, provided the ablation was confined

within certain limits of quantity, the animal recovered its intelligence after the wound was healed. It appeared, however, that when the quantity removed exceeded a certain limit, the faculties were enfeebled ; and by increasing the quantity removed, they totally disappeared.

418. If one only of the cerebral hemispheres be removed, care being taken not to compromise in the operation any other part of the encephalon, a general feebleness of the opposite side and complete blindness of the opposite eye will ensue ; but the intellectual powers of perception, will, memory, and so on, will remain undisturbed. There is, therefore, a cross physiological action of this part of the encephalon, which cross action, nevertheless, does not extend to the faculties of perception and will.

419. The removal of both cerebral hemispheres destroys all perceptions, and consequently that of sight ; but from what has been just explained, it appears that in the destruction of sight the removal of the two hemispheres produce separate effects : the removal of the right hemisphere destroying the perception of the left eye, and that of the left hemisphere the perception of the right eye.

420. **Function of the Quadrigeminal Tubercles.**—The removal of the quadrigeminal tubercles, the cerebral lobes remaining untouched, also produces blindness ; and in this case, as in the former, there is a cross effect,—the removal of the right tubercles destroying the sight of the left eye, and *vice versâ.*

But between the blindness produced by the removal of the cerebral lobes, and that which ensues from the removal of the tubercles, there is a remarkable difference. In the former case, the organs of vision, as has been already explained, retain all their functions, and what is lost is, strictly speaking, not the *sense*, but the *perception* of sight. The impressions are transmitted, the retina, the optic nerve, and tubercles all discharging their duty ; but the recipient of the sensitive impression, by which alone that impression could be perceived, is absent, and no consciousness of vision ensues. The organ of sense, in short, discharges its functions, but has no organ of mind to act upon.

In the latter case, on the contrary, the optic nerves which terminate in the tubercles are cut off, and the sensible impression is arrested in its passage to the organ of perception. The

organ of perception is present in all its integrity, and the power of perception exists unimpaired; but the action of the organ of sense upon it is intercepted.

421. **Experiment of Flourens.**—One of the experiments of M. Flourens illustrates these principles in a manner so striking that we shall here quote it:—

The case of a fowl rendered blind by the ablation of the cerebral hemispheres, has been already described; let us compare it with that of a similar animal, rendered blind by the ablation of the bigeminal tubercles.

Although completely deprived of sight, this animal moved about, directed its steps, heard, remembered, sought for, and selected its food, climbed every evening, about the same time, to roost upon the same table, received and sympathised with the caresses of its mate, turned aside from the obstacles it encountered; and, except when alarmed, took its measures so effectually, and moved about with so much precaution, that it seemed to feel the objects in its way almost before encountering them.

It pecked its food as it walked, swallowing the good grains, and rejecting the bad.

The former fowl, rendered blind, never pecked at all, and swallowed everything indifferently that was thrust sufficiently far into its mouth.

The latter fowl knew perfectly the place where its food was deposited, remembered the hours at which it was brought there, and never failed to seek it when hungry. If the place of the food was changed, it was restless until it discovered it.

"This curious animal," says M. Flourens, "conducted itself in all circumstances with an intelligence so much the more fine, constant, and apparent, as, having lost its sight, it was obliged to supply that sense by all the resources which its other senses, guided by its intellectual faculties, could supply."

422. In a word, by comparing the two cases here referred to, it was apparent that the animal deprived of its bigeminal tubercles lost nothing but its sight, its other faculties being rendered even more acute than before; while the animal rendered blind by the ablation of the cerebral lobes lost, with its sight, all its perceptive, voluntary, intelligent, and instinctive faculties.

423. **Function of the Cerebellum.**—We have shown in a preceding paragraph that the power of regulating the complicated action of the motor nerves on the muscular fibres is distinct from the faculty of the will, of which the cerebral lobes are the exclusive seat. It appears, from numerous experiments of physiologists, and especially from those of M. Flourens, that this regulating faculty resides in the cerebellum. If that part of the brain be injured or removed, the regulating power will cease; and although the animal will retain all the powers of

locomotion in its members, and the faculty of will unimpaired, all steadiness and regularity of motion will disappear. It will no longer be able to hold itself in equilibrium, nor to walk nor fly with steadiness and regularity. It is in a state of constant uneasiness and agitation. It wills and it moves, but it cannot move as it wills.

The gradual removal of the cerebellum produces a gradual privation of the equilibrium and regularity of locomotion. The greater the injury the greater the unsteadiness. Total ablation destroys all steadiness and regularity.

The want of regulating power in each species is shown more especially in the peculiar mode of locomotion which is proper to it. The bird which walks, such as the turkey or ostrich, shows it in its gait; the bird which flies, such as the swallow, shows it in its flight; the aquatic bird shows it in its swimming.

The cerebellum then is the seat of the regulating and equilibrating power, and must include in its structure some corresponding principle.

The species of cross effect which has been indicated in the cerebrum and quadrigeminal tubercles also prevails in the cerebellum. The lesion of the right side produces its effects on the left, and *vice versâ.*

424. All the results of Flourens' experiments, by which these functions of the cerebellum were ascertained, have been fully confirmed by those of Hertwig.

425. **Experiments of Magendie.**—Magendie made numerous experiments on the functional properties of the subordinate parts of the encephalon; and although he does not appear to have developed laws, having the same generality and simplicity as those which were manifested in the researches of Flourens, some phenomena of considerable interest were disclosed.

Thus, when he divided the corpora striata (fig. 242, [12]), he found that the animal thus mutilated no longer remained master of its movements, but appeared to be impelled forward by an irresistible inward power. It launched itself constantly forward, ran with rapidity; and, in fine, stopped, but never recoiled.

He found, in certain cases, that the lesion of the cerebellum deprived the animal of all power of moving *forwards*, but that it moved readily backwards.

He also found, that when one side of the cerebellum, or of the pons Varolii, was cut, the animal was affected by a rotatory motion, bearing always towards the wounded side, and sometimes so rapidly as to make

sixty revolutions per minute. This vertiginous motion was sometimes observed to be continued for a week without cessation.

It appeared from the researches and experiments of Magendie, that certain kinds of injury to the medulla oblongata impart to the animal a tendency to move in a circle, as horses do when they are trained in a ring. From such experiments he inferred the existence of certain impulses in the brain which oblige the animal to move in certain directions, forwards or backwards, right or left. His hypotheses to explain these phenomena were that, in the normal state of the encephalon, such impulses balance each other, and that by the destruction or injury of any part, the equilibrium is destroyed.

426. **Cross Effects.**—Hertwig found that a dog, of which the pons Varolii was wounded on the right side, was affected with a similar vertiginous motion, turning always to the left.

The cross effects which have been here indicated appear to be confined to the cerebrum, the cerebellum, quadrigeminal tubercles and other subordinate parts, but not to extend to the medulla oblongata or the spinal cord. In these, any irritation applied to either side produces an effect upon the same side, although the contrary might be expected in the medulla, considering the crossing of the columns of the spinal cord which takes place just below it (fig. 250.)

427. **Functions of Medulla Oblongata.**—Having explained the principal functions of the other parts of the cerebral axis of the nervous system, it remains to notice the peculiar properties of the medulla oblongata.

This part of the column being the medium of communication between all the nerves of the body and the brain, necessarily possesses all the properties in relation to these nerves, which are found in the lower parts of the spinal cord. Thus the transverse section of any part of the medulla oblongata will necessarily deprive all the lower parts of the body of sensibility and voluntary motion. But, independently of this, the medulla has properties peculiar to itself, which have been demonstrated by the same method of exclusion, which has been so successfully applied to the investigation of the other cerebral functions.

If the spinal marrow be removed from all the lumbar and dorsal region of the column, no other effect will ensue, except the paralysis and insensibility of the lower parts. The ablation being continued gradually upwards along the dorsal part, the respiration will be found to be, at first slightly,

and afterwards more perceptibly weakened. Being continued to the superior limit of the dorsal region, all action of the ribs will cease, and respiration will only be effected by the diaphragm, a part whose action will be explained hereafter.

By continuing the ablation further upwards, the action of the diaphragm ceases, and the animal barely lives by gasping.

In fine, the ablation being brought a little further, respiration completely ceases, and life with it.

The point at which this effect is produced, coincides with the origin of the glosso-pharyngeal and pneumogastric nerves (figs. 244^{31} and 244^{32}).

428. It appears therefore that the vital functions continue their play unimpaired after the removal of the entire spinal cord to the intercostal region ; that, above that point, they are still maintained subject only to respiration, more or less impeded; that when the cord is removed from the origin of the phrenic or diaphragmatic nerves, all respiration is reduced to gasping, and in fine ceases, and life becomes extinct when the ablation extends to the origin of the glosso-pharyngeal and pneumogastric nerves (fig. 244^{31}, fig. 244^{32}).

If, instead of proceeding upwards from the base of the vertebral column, the ablation of the cerebral matter be commenced from above, it will be found that the removal of the cerebral hemispheres, the cerebellum, and other subordinate parts, will not produce any suspension of the vital functions, but that when the excision is carried to the point above indicated at the origin of the glosso-pharyngean and pneumogastric nerves, life will suddenly become extinct.

429. It must, however, be observed, that in birds where the diaphragm is absent, the phenomena are somewhat modified. In these classes, life ceases with the removal of the dorsal part of the spinal cord.

430. Amphibious reptiles, such as salamanders and frogs, being deprived of movable ribs, the muscles of the throat and the hyoidean apparatus discharge the respiratory functions of the diaphragm, and it is accordingly at the origin of the nerves which supply this part, that the removal of the medullary matter causes the immediate cessation of life.

431. **The Vital Point.**—It appears, therefore, that the vital principle in all mammifers resides in that point of the medulla oblongata at which the glosso-pharyngean and pneumogastric nerves have their origin. While the maintenance of the vital functions is incompatible with the ablation of the medullary matter, at this point they will continue, even though every other part of the encephalon and spinal cord be removed. The

other parts of the nervous system can only continue to discharge their functions so long as they are connected with each other and with this single point.

The existence of such a vital point was assumed by physiologists long before it was demonstrated and its position determined. Lorry was the first who ascertained that in the nervous apparatus a point existed, the section of which produced sudden death, while a like section made either above or below such point did not produce the same phenomenon. He added, that this point was found between the first and third vertebræ.*

The vagueness of this determination was probably the cause which turned the attention of physiologists from a discovery of such capital importance. Le Gallois resumed the question, approaching somewhat nearer to the exact position of the sought point, defining its situation at a little distance from the foramen magnum, towards the origin of the eighth pair or pneumogastric nerve.†

It was, however, reserved for M. Flourens to establish the exact position of the vital point by experiments on various animals, such as have been described above.

432. **Functions of the Ganglionic System.**—The structure and disposition of the ganglionic system, or great sympathetic nerve, has been already explained. This, which is connected at various points with the cerebro-spinal system, produces and regulates the involuntary organic motions by which circulation and nutrition are maintained, as the cerebro-spinal system controls and regulates voluntary motion. It has been the prevalent opinion of physiologists that the sympathetic nerve, possessing no excitability, is also destitute of sensibility. Experiments were made by Bichat, Wutzer, Lobstein, and many other physiologists, with the express view of testing its sensibility. The semilunar ganglion was denuded upon several animals by Bichat, and, being irritated, no signs of sensibility were apparent. Wutzer and Lobstein repeated the experiment with the same results. Flourens, however, was more successful, and has proved that this ganglion, being irritated, produces manifest signs of sensibility. No such signs, however, were obtained in the same

* Académie des Sciences, Mémoires des Savans Etrangers, t. iii. p. 368.

† Le Gallois, Expériences sur le Principe de la Vie, p. 37.

unequivocal manner from other parts of the ganglionic system. Flourens infers from this, that the semilunar ganglion, 270 [48], is the connecting link between the cerebro-spinal system and the great sympathetic nerve, and that the opinion so long prevalent of the dependence of the ganglionic upon the cerebro-spinal system, is thus, if not confirmed, rendered highly probable.

433. **General Summary of the Nervous Functions.**—In fine, from all that has been stated in the present Chapter, it will be perceived that each part of the nervous system is endowed with a distinct and peculiar function. The cerebrum does not act like the cerebellum, nor the cerebellum like the medulla oblongata, nor the medulla oblongata like the spinal cord and the nerves. Each part has its proper and special function.

In the cerebral lobes resides the faculty in virtue of which the animal thinks, wills, remembers, judges, perceives its sensations, and dictates its movements.

In the cerebellum resides the faculty which regulates and equilibrates locomotion.

In the quadrigeminal tubercles is placed the perceptive principle of vision.

In the medulla oblongata is established the excitor and director of respiration.

In the spinal cord, in fine, is established the connection of all the partial movements excited by the nerves in the members.

There are three nervous properties essentially distinct: *excitability*, by which motion is transmitted from the seat of will; *sensibility*, by which sensations are transmitted to the same seat; and *intelligence*, by which excitability is directed, and sensibility perceived.

Each of these properties has its proper origin.

Excitability is established in the anterior part of the spinal cord and the anterior roots of the nerves; sensibility, in the posterior part and posterior roots of the nerves; and intelligence, in the brain, properly so called.

No motion is derived directly from the will, which is only the remote and exciting cause of motions. Motions are produced by muscular contraction, the immediate cause of which resides in the spinal cord and the nerves, the regulating principle being established in the cerebellum.

In the production of any given motion there are, therefore three phenomena which are essentially distinct: 1, the volition, the seat of which is the cerebral hemispheres; 2, the regulation and equilibration of the various nervous forces necessary to act upon the muscles, the seat of which is the cerebellum; 3, the excitation, producing muscular contractions, a faculty which has its seat in the spinal cord and the nerves.

Since these three important phenomena, essentially distinct, are exhibited in these organs, also essentially distinct, it is evidently possible to abolish any one of the three, the other two being unimpaired; and such is the principle upon which the method of exclusion, so successfully practised by contemporary physiologists, and above all by M. Flourens, is based.

An animal deprived of its cerebral lobes loses all spontaneous and voluntary motion, yet, when it does move, it moves as regularly as when it possessed its lobes.

An animal deprived of its cerebellum, on the contrary, loses all regularity and equilibrium in its motions; yet all the other organs and members of such an animal, the head, trunk, extremities, move, but their movements are purposeless and irregular. Such an animal no longer walks, flies, or stands upright; not because it has lost the use of its legs or wings, but because the regulating principle of their motions no longer exists. In a word, all the partial motions still exist, but the principle which regulates them is lost.

What the cerebellum is to the movements of locomotion, the medulla oblongata is to those of organic conservation. So long as the medulla exists, organic life continues; with its removal, vitality ceases.

The function of respiration, and its concomitant movements, is commonly denominated involuntary, in opposition to those which govern locomotion. The terms voluntary and its opposite must here, however, be taken in a qualified sense. Respiration, crying, sighing, yawning, and various concomitant actions, are dependent on the will only to a certain extent, and in certain cases. All these movements may take place without its participation, and often even in opposition to it.

The organic movements of the apparatus of circulation and nutrition are absolutely foreign to the will.

There are, therefore, in relation to the will, three classes of motions: first, those which are absolutely dependent upon it, as those of the members of locomotion; second, those which are partially dependent upon it, as those of respiration; and third,

in fine, those which are wholly independent of it, as those of organic life.

The parts of the nervous system are subordinate one to another, and all to one. The nerves and spinal cord are subordinate to the encephalon, and the whole system to the vital point in the medulla oblongata.

In fine, the result of the analysis of the cerebral functions is the establishment of the unity of the organ of intelligence. Not only all the perceptions, all the volitions, all the intellectual faculties, reside exclusively in the cerebral lobes, but all these faculties occupy them in common. When by the lesion of any given point of these lobes, one faculty disappears, all disappear; and when, by the cure of such lesion, one faculty returns, all re-appear. Perception, will, memory, and the other acts of the mind are, therefore, not several distinct faculties, but one single faculty—intelligence, which faculty has one single seat, the cerebral lobes.*

* Flourens' Recherches, chap. xv.

CHAPTER VI.

CIRCULATION.

434. **Waste of the Body.**—In all vital motions, whether voluntary or involuntary, more or less of the unorganised matter composing the body is thrown off, being, as it were, used and worn out. If this were to be continued indefinitely, the body would be gradually wasted away, and at length the matter remaining would be insufficient in quantity to maintain its vitality. A provision is therefore necessary to replace this constant waste.

435. **Growth.**—But, independently of this, the body and its organs, during the period from birth to maturity, are constantly increasing in volume and weight. During that period, therefore, an increment of the materials out of which organised matter is formed, must be supplied to it in sufficient quantity not only to replace the waste already mentioned, but to supply the matter constituting the growth; and this latter portion is much more considerable than the former.

436. **The Blood.**—The source from which all this supply of the constituents of the body is more immediately derived is the *Blood*, which has therefore been called the nourishing fluid. It is diffused through all parts of the system by a suitable hydraulic apparatus specially adapted to this purpose.

But since it thus supplies the constituents necessary to replace the waste of the body, the blood itself must be supplied with these very constituents, or at least of the physical principles out of which they can be produced. This is accordingly accomplished by a suitable apparatus, by which the necessary constituents are educed, partly from food by the process of digestion, and partly from the surrounding air by the process of respiration.

It appears, therefore, that the processes of circulation, respiration, and digestion, are correlative and mutually dependent.

437. **Its Composition.**—That the blood is suited to the

maintenance of the body is proved by its analysis ; from which it appears, that the materials of which it is composed are precisely the same, and enter into its composition in precisely the same proportion. Thus, like the body, the blood contains from 77 to 79 per cent. of water, the remainder consisting of albumen and fibrine, with other organic compounds, also phosphate of lime and other earthy salts, all of which enter into the formation of the body.

438. **Transfusion.**—Physiologists have proved, by direct experiment, that not only the blood itself, but each of its component parts, is the source by which the vital functions are sustained. When an animal is bled abundantly it becomes gradually more feeble ; and, if the hæmorrhage be continued, fainting and loss of consciousness ensues, respiration is suspended, all muscular action, involuntary as well as voluntary, ceases, and no external sign of life is manifested ; and if the animal be left in this state, death ensues.

But if into the veins of the body, thus apparently deprived of life, a quantity of blood be injected, similar to that which it has lost, vitality will be immediately restored ; and according as the quantity of blood thus received is increased, the animal is more and more reanimated, respires more freely, moves with facility, and recovers its habitual state.

439. **The vital properties of the constituents of the blood** have been severally ascertained by this process of transfusion. It will be presently shown that blood consists of certain minute solid discs of a red colour floating in a liquid called *serum*. If the blood thus transfused be previously deprived of these red discs, it will produce after transfusion no more vital effect than would so much pure water, and the death of the animal would follow the hæmorrhage as inevitably as if no such transfusion had taken place.

In the serum of the blood thus mentioned, *fibrine* is one of the constituents, and this fibrine is one of the constituents of the bones and muscles. M. Magendie having bled a dog, injected into its veins an equal quantity of blood divested of its fibrine. The animal soon fell into a state of extreme weakness, and died after some days, having manifested all the symptoms which attend certain destructive fevers.

440. **The Organs increase according to the blood they**

receive.—Experiments have been contrived to demonstrate this. Thus, when by artificial means part of the blood-vessels which supply an organ are intercepted, the organ is observed gradually to decrease in magnitude, and often even to wither away, and almost disappear. On the other hand, it is found, that in proportion as the blood received by it is more abundant, the more also its bulk is increased. Now, it has been ascertained that the flow of blood to any organ is stimulated by muscular action, and it is found, accordingly, that the more an organ is exercised the more its power is developed and its volume augmented. The exercise, therefore, in this case, is only the cause of the increase of the organ in so far as it produces an increased supply of blood to it. Thus we see the muscles of the legs, and especially those of the calves and thighs, remarkably developed in dancers ; those of the arms and shoulders in blacksmiths and others whose occupations involve a constant and violent exertion of these members. The benefits arising from gymnastic exercises, properly regulated, are similarly explained, the effects consisting in the stimulus given to the flow of blood to the several organs, which reacting on the circulation generally, produces a similar stimulus upon all the functions involved in the formation of the blood itself.

441. **Blood is not an homogeneous fluid** holding in solution certain substances, and destitute of all solid and concrete matter ; if it were so, we could not follow its course through the vessels in which it moves, as we do so easily and distinctly with the microscope. The motion of an homogeneous liquid in tubes completely filled with it could not be made sensible to the sight ; but on the other hand, the solid particles in it are so infinitely minute that a drop of blood no larger than might be suspended from the point of a needle contains myriads of them. These corpuscles are distinguished by regular and constant forms, by a complex composition and a determinate structure. They possess a real organisation, and pass through a regular succession of phases, having a beginning, a development, and an end.

442. **Blood Globules.**—They consist of three species : first, red corpuscles ; secondly, white globules ; and thirdly, white granular particles, much smaller, to which observers have applied the name "globulines."

Nothing can be more simple or more easy than the method

of observing the first class of these corpuscles. Take a sharp needle and prick with it slightly the end of the finger, so as to draw the smallest drop of blood; having previously rendered a small slip of glass perfectly clean and dry, touch it with the blood, a small portion of which will adhere to it, and upon this lay a thin film of glass, such as is prepared by the opticians for microscopic use, so as to flatten the blood between the two glasses. Let the glass thus carrying the blood be placed under a microscope having a magnifying power of about

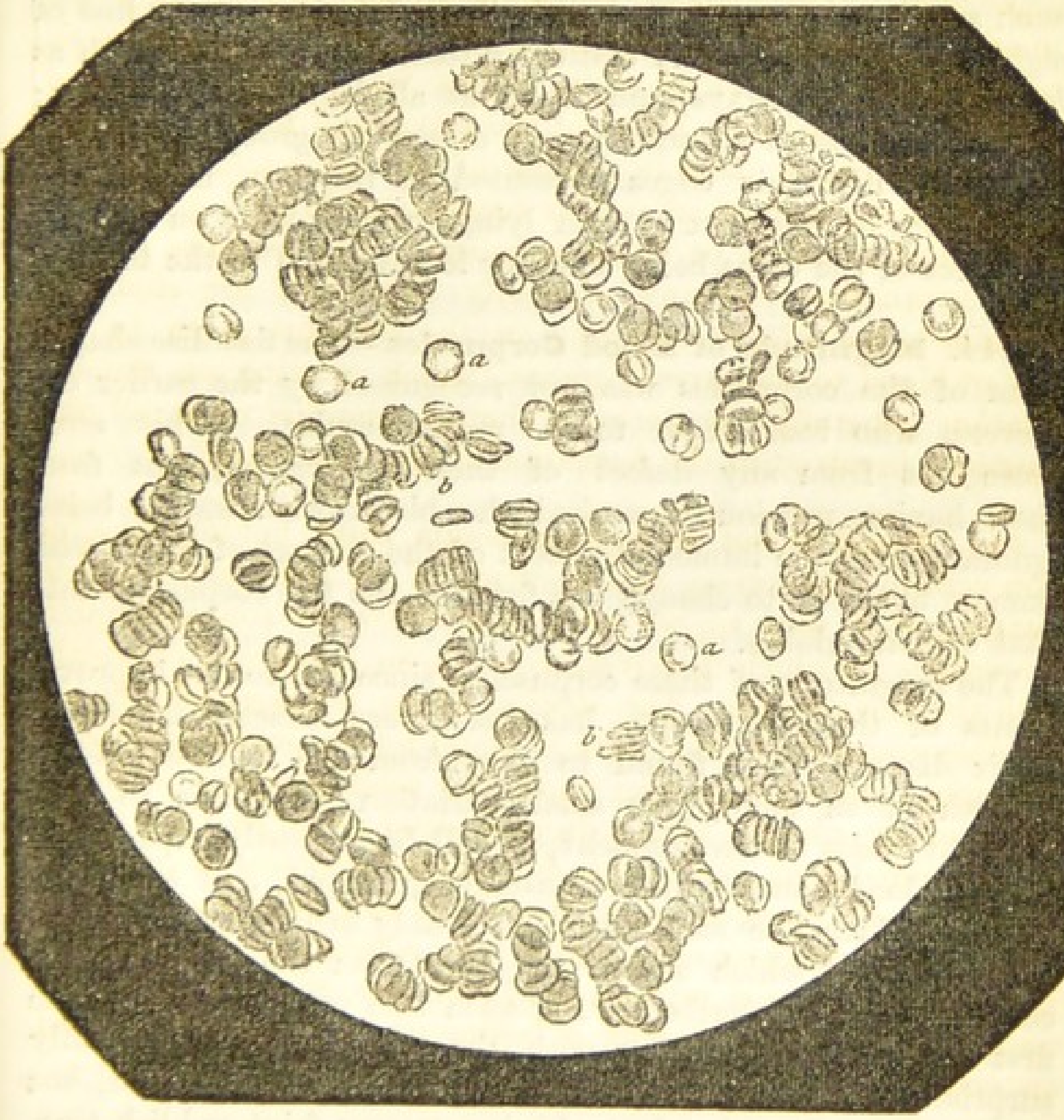


Fig. 309.

VIEW OF A THIN DISC OF HUMAN BLOOD, PRESSED BETWEEN TWO PLATES OF GLASS, THE REAL DIAMETER OF THE PART SHOWN BEING THE 120TH OF AN INCH, DAGUERREOTYPED BY MESSRS. DONNÉ AND FOUCAULT.

400 diameters; a multitude of the red corpuscles will then be

immediately visible, distributed irregularly over the field of view of the instrument.

443. **The Experiments of Messrs. Donné and Foucault** supplied microscopic daguerreotypes of drops of blood showing the globules here described floating in the serum. One of these engravings is here reproduced by the permission of the publisher.

The red corpuscles alone are here visible; their form is that of flat discs a little concave in the middle, swelling upwards towards the edges, which are slightly rounded. Some of them, such as *a a a*, are presented with their flat sides to the line of sight, so as to show very distinctly their form; others, such as *b b*, are seen edgeways, and others at all degrees of obliquity; some are scattered separately, and others are grouped together in piles with their edges presented to the eye, having the appearance of rouleaux of coin lying on their sides on a table, the faces of the coins being more or less inclined to the table.

444. **Magnitude of Blood Corpuscles.**—The flat disc-shaped form of the corpuscles was not recognised by the earlier observers, who took them to be red spherules. This error arose not from any defect of their observation, but from their having previously washed the blood with water, being ignorant that the immediate effect of the contact of water with human blood is to change the form of the flat corpuscles into that of little globes.

The magnitude of these corpuscles, since the recent improvements of the microscope, has been very exactly measured. Their diameters are found to vary from the 3125th to the 3000th of an inch; this small variation being due to their different states of development, as will be presently explained.

The blood consists of a transparent, limpid, and colourless fluid, in which the solid particles already mentioned float, and the redness of which arises altogether from the colour of the corpuscles here described. A person who may observe for the first time these corpuscles with the microscope, is generally surprised and disappointed to find that they are not red, but rather of a yellowish colour, having a very faint reddish tint. This circumstance, however, is an optical effect of a very general class. When any coloured medium is submitted to the eye, the depth of its tint will always be diminished with the thickness of the medium, which may be reduced to such a degree of tenuity as to render its peculiar colour altogether imperceptible.

The case of coloured wine, such as sherry, viewed through a tapering Champagne glass, presents an example of this. At the upper part, where the eye looks through a greater thickness of the liquid, the peculiar gold colour is strongly pronounced; but in going downwards to the point of the cone, the colour becomes paler and paler, and at the very point is scarcely perceptible. It is the same with the red corpuscles of the blood. When they are seen singly through their very minute thickness, they appear of the faintest reddish-yellow; seen in rouleaux edgeways, they are redder; but it is only when amassed together, in a stratum of blood of some thickness, that they impart to the liquid the red colour so characteristic of the blood.

The disc-shaped form which thus characterises the corpuscles of human blood, is common to all species of animals which suckle their young, with the single exception, so far as is known at present, of the camel species. It appears, from some observations of Dr. Mandl, that the blood of this species presents an exception, the red corpuscles being elliptical in their form, but still flat and concave.

In comparing the red corpuscles of the blood of different species of mammifers, one with another, they are found to vary in their diameters, being greater or less in different species, but the variation in each species being confined within narrow limits, as in man.

The corpuscles of the blood of birds, fishes, and reptiles, are all oval discs of various magnitudes, somewhat concave in their centres.

445. **White Corpuscles.**—The discovery of the white globules is entirely due to recent observers, and particularly to Professor Müller, Dr. Mandl, and Dr. Donné.

The white globules have nothing in common with the red corpuscles, either as to colour, form, or composition. Unlike the latter, they are spherical, their contour is slightly fringed, and not well defined like that of the red corpuscles; their surface is granulated, and their diameter is a little greater, varying from the 2500th to the 3000th of an inch. They appear to consist of a thin vesicle, or envelope, the interior of which is filled with solid granulated matter, consisting usually of three or four grains, while the red corpuscles are filled with an homogeneous and semifluid matter in the case of mammalia, and a single solid kernel in the case of other vertebrated animals.

The white globules also have chemical properties totally different from those of the red corpuscles.

In fine, the third class of solid particles which float in the blood cannot be properly denominated globules, being only very minute granulations, which are continually supplied by the chyle to the sanguineous fluid; they appear in the microscope as minute roundish grains, isolated, or irregularly agglomerated, and having a diameter not exceeding the 8000th of an inch: they have, however, a physiological importance of the first order, since they are the primary elements of the blood, and therefore of all the other organised parts of the body.

It appears to follow from the observations, researches, experiments, and reasoning of Dr. Donné, that these granular particles form themselves into the white globules by grouping themselves together, and investing themselves with an albuminous envelope. By a subsequent process, the white globules are converted gradually into the red corpuscles, the place where this change is produced being supposed by Dr. Donné to be the spleen. The question, however, of the mode and place of formation of the red corpuscles has not been finally settled.

In fine, the red corpuscles, after having been fully developed, are dissolved and converted into a fibrinous fluid, and pass into the organs to the nourishment of which they contribute.

446. **Circulation.**—Since, therefore, the blood is the means of nourishing and repairing the waste of all parts of the system, it is evident that it must have a corresponding diffusion, spreading itself through all parts of the body which it thus sustains; and since after parting with its nourishing constituents it is vitiated and deprived of its nutritious quality, it is necessary that it should be conducted to some parts of the system where that quality can be restored to it; and when this is accomplished, the blood, having recovered its nourishing power, must return to the organ by means of which it is again propelled through the system.

It will be evident from this brief statement that the functions of the blood are essentially circulatory. It makes a circuit, and machinery constructed on a circulatory principle must be provided for it. It is propelled from the organ in which it is elaborated to the extreme points of the system, and back from these to a collateral organ, where it is reconstituted. As it nourishes all parts of the body, it must be infinitely diffused, and the canals and tubes by which it is conveyed to and fro

must be provided with branches and ramifications infinitely numerous; and as the multitude of these is so great, and their consequent magnitude so small, the propelling apparatus must be endowed with a considerable mechanical power.

447. **Illustration of the Circulating Mechanism.**—To convey the first general notion of the principle upon which the circulating machinery of the human body, and that of most of the superior animals, is constructed,— without attempting, however, for the present to represent the particular form or position of its parts,—

Let us suppose the blood, properly prepared to nourish the organs, to enter a tube A, fig. 310, in the direction indicated by the arrow, and to pass through a valve *n* into the instrument B C, by which it is to be propelled through the body. This instrument consists of two compartments, B and C separated by a partition having in it a valve *o* which opens from B to C. In C there is another valve *p*, which opens into the pipe D, through which the blood is propelled through the system. Let O represent one of the organs which the blood is intended to nourish; it traverses this organ by means of an infinite number of small tubes, through the coatings of which it conveys the nourishing principles, receiving what is rejected by the organ in exchange. The two principles thus pass through the membranes of which the blood-vessels are composed, in contrary directions, one passing from the tube into the organ, and the other from the organ into the tube by the principle of endosmose and exosmose.*

The blood after thus giving up its nourishing constituents, being no longer capable of discharging its vital functions, is driven through the valve *m′* through the tube A′, and the valve *n′* into another propelling instrument B′ C′ similar in all respects to B C, already described. The tube A′, before it enters the propelling instrument B′, receives another tube F inserted into it near the valve *n′*. This tube F conducts another fluid consisting of certain nourishing principles called *lymph* and *chyle*, which are elaborated from the food. This lymph and chyle flowing through F are driven through the valve *n′* mixed with the blood which came from O through A′, so that the propelling instrument B′ C′ is filled with the used or spoiled blood mixed with lymph and chyle. This mixture is propelled by B′ C′ through the valves *o′ p′* into the pipe D′, and thence through the valve *q′* into the organ L. There it is diffused and placed in contact with atmospheric air supplied by respiration through the tube G. It parts with a large portion of carbon, in combination with oxygen previously received from the air inspired, forming carbonic acid, which escapes through G. In fine, in this organ L the blood is elaborated, the lymph, chyle, and atmospheric air supplying it with all those nourishing and vital principles of which it had been deprived in passing through O, and taking from it those which would render it unfit for vital action. Thus prepared, it passes through the valve *m* into the tube A, and thence through the valve *n* into the propelling apparatus, and so on.

Let us suppose that the sides of the compartments B C and B′ C′ have

* See Lardner's Handbook of Natural Philosophy, Hydrostatics, § 113 et seq.

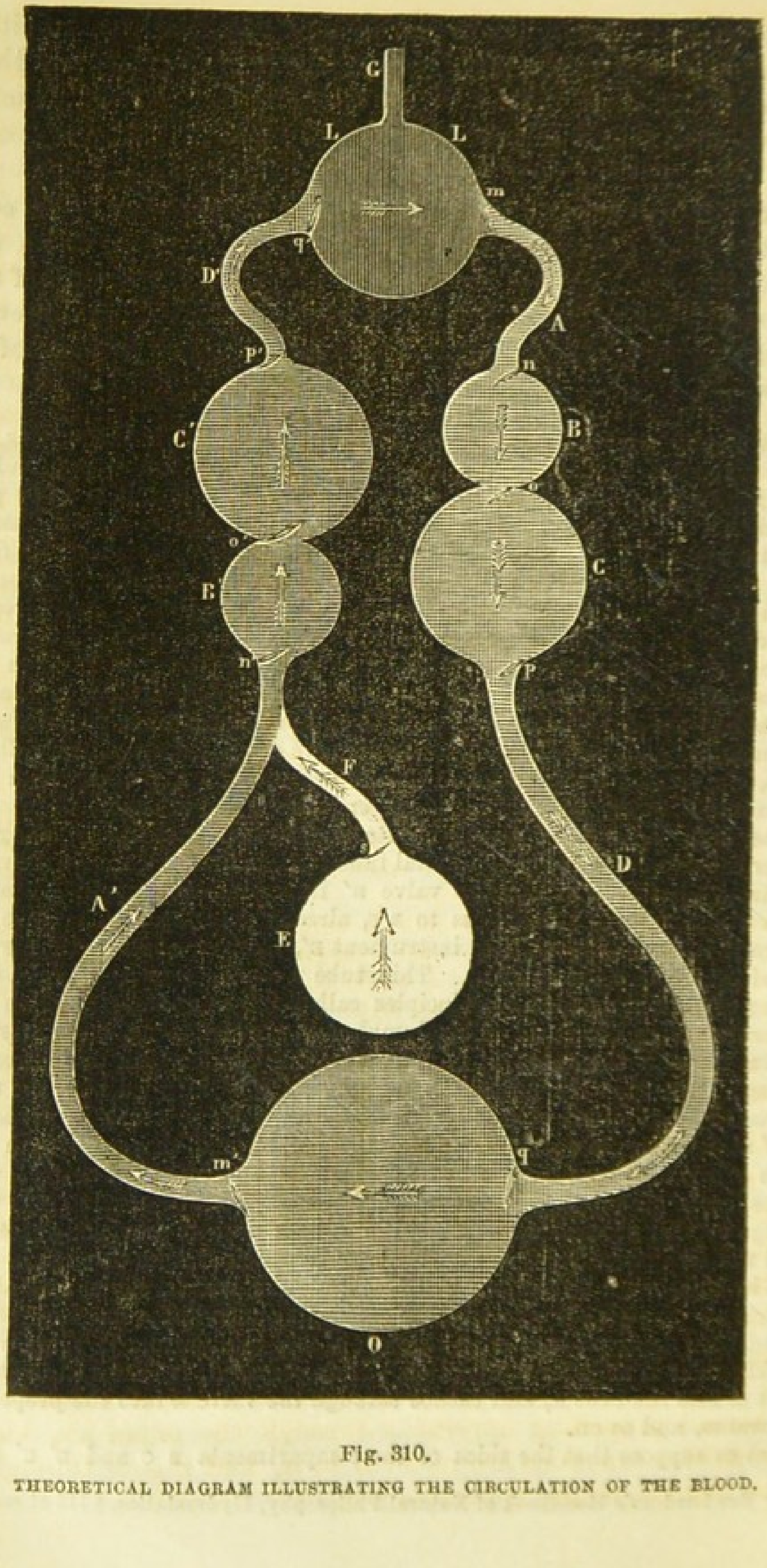


Fig. 310.

THEORETICAL DIAGRAM ILLUSTRATING THE CIRCULATION OF THE BLOOD.

a contractile power like that of the muscles, and that in virtue of this power, they are alternately contracted and relaxed. When the sides of B are relaxed, the valve *n* being relieved from the inward pressure is opened by the pressure of the blood in the tube A, and the compartment B is immediately filled. Meanwhile the flow of blood from A relieving the valve *m*, that valve is opened, and A is replenished by blood from L.

While the sides of B were relaxed, those of C were contracted so that the valve *o* was kept closed. But so soon as the compartment B is filled with blood, the contraction of the sides of the compartment C ceasing, and the contraction of those of B commencing, the valve *o* is opened, while *n* is kept closed and blood is driven from B to C. After this, the sides of B relax, and those of C contract, and blood is driven through the valve *p* into the pipe D and through the valve *n* into the compartment B, and in this way, by the alternate contraction and relaxation of the sides of the two compartments B and C, blood passes from L to A and from B to C, and then from A to B and C to D. There is thus a continual pulsation produced in the current of the fluid, the propelling power acting not continuously, but with intermission, like the piston of a forcing pump which has no air-vessel, or that of a steam-engine having no fly-wheel.

The tube D is however also endowed with a contractile power, which acting upon the blood aids in propelling it forwards through O to the second propelling apparatus B′ C′. By such means the nourishing fluid is driven forwards by a succession of pulsations through the organ O, the valve *m′*, the pipe A′, and the valve *n′* carrying forwards in its current the lymph and chyle which flows through F into the second propelling apparatus B′ C′. This latter propelling apparatus is constructed on precisely the same principle, and acts in precisely the same manner as does the first B C. The sides of the compartment B′ are contracted and relaxed simultaneously with those of B, and the sides of C′ simultaneously with those of C. By these means, the spoiled blood mixed with lymph and chyle is driven through the tube D′ into L in the same manner exactly as that in which the nourishing blood was driven through D into O.

It will be evident that the propelling powers exerted by C and B respectively, ought to be proportional to the resistances which the blood encounters in passing through D, C, and A′ on the one hand, and through D′, L, and A on the other. But the latter series of tubes and vessels being less in length and extent, and on other accounts opposing less resistance to the fluid, the propelling mechanism of B′ C′ ought to be proportionally less powerful than that of B C.

448. **Great and Lesser Circulation.**—It appears, therefore, that the blood is subjected to two distinct processes of circulation. These are called the *great* and the *lesser circulation.* In the great circulation, the blood is driven by the apparatus B C to the organs which it nourishes, and after it has discharged its nutritive functions it is propelled back to the apparatus B′ C′, having previously received the lymph and chyle from F.

In the lesser circulation, the blood thus vitiated is driven by the second propelling apparatus through the organ L L, where the nutritive functions are restored to it, and thence through A to the first propelling apparatus B C.

The purpose, therefore, of the first and great circulation is to nourish the organs, and that of the second is to reconstitute the blood.

The organ L L, in which the blood is reconstituted, represents the *lungs.*

449. **Red and Black Blood.**—It is evident that the blood which flows through the tube A, the propelling apparatus B C, and the tube D, differs essentially from that which passes through the tube A′ and the propelling apparatus B′C′, inasmuch as the former possesses the power of nutrition, of which the latter is altogether deprived. These fluids differ also in their sensible qualities, the nutritive blood having the colour of bright vermilion, and the vitiated blood being a brownish red.

450. **Auricles and Ventricles.**—Such is the mechanism of the circulation taken in the most general point of view, and apart from any consideration of the peculiar form and disposition of its parts. It is scarcely necessary to say that the actual form and arrangement of the parts are totally different from those shown in fig. 310. Nevertheless, as will presently appear, the principle is the same.

The two propelling apparatus B C and B′ C′ constitute the heart, which consists of four compartments, corresponding in their mechanical structure and functions to B C and B′ C′. The two lesser compartments B and B′ into which the blood is first propelled on each side are called *auricles,* and are distinguished as the right and left auricle; B, which receives the nourishing blood, being on the left side; and B′, which receives the spoiled blood, being on the right side of the heart, and both being at its upper part, and not as in the figure, one above and the other below. The second and larger compartments C and C′, which receive the blood from B and B′, are called *ventricles,* and, like the former, are distinguished as the right and left ventricles, the left ventricle being that through which the nourishing blood, and the right, that through which the spoiled blood, passes.

451. **The Aorta.**—The pipe represented by D in the figure is a great tube issuing from the heart, called the *aorta,* which, however, instead of being a single continuous tube, as we have taken it to be merely to simplify the illustration, diverges into several branches soon after leaving the heart, and these branches again ramify into others, which in their turn throw out still more numerous and smaller ramifications, until the body and all its members and organs are penetrated and overspread with tubes, which at length become so minute that they are called

capillaries, from the Latin word *capilla,* signifying *a hair.* It is in these capillaries chiefly that the process of nutrition goes on; and from them the blood, no longer possessing nourishing properties, passes, not into a single tube A′, which we have assumed it to do for the sake of illustration, but into a multitude of small tubes, which, running gradually into each other and increasing in size, terminate in one or two large tubes, which, after receiving the lymph and chyle from F, discharge the blood into the right auricle B′, which passes from thence into the right ventricle C′, as already described.

The lungs instead of being single, as we have represented them in the figure, for the sake of illustration, are double, being distinguished as the right and left lung. The tube D′ diverges into two, called the *right and left pulmonary arteries;* and the tube A consists of four, two proceeding from the right lung, which unite in one before entering the auricle B, and two others, proceeding from the left lung, which also unite in one before entering the same auricle. These are called the *right and left pulmonary veins.*

452. **Arteries and Veins.**—The tubes through which the blood circulates, whether great or small, and whether near to or distant from the heart, are called *blood-vessels.* Those through which the blood flows from the heart to any other part of the body are called *arteries,* and those through which the blood returns to the heart are called *veins.* Those which connect the heart with the lungs, and which form the apparatus of the lesser circulation, are distinguished from the others as *pulmonary arteries and veins.* Thus, in the illustrative diagram, the tube D represents the arteries, and A′ the veins; and as the blood which flows through D is nutritive or red blood, and that which flows through A′ is vitiated or black blood, the former is generally called *arterial,* and the latter *venous* blood. It must be observed, however, that in the pulmonary system of blood-vessels the character of the blood which they conduct is reversed; the pulmonary arteries are represented by D′, conducting vitiated or black blood, while the pulmonary veins, represented by A, conduct nutritive or red blood.

453. **Lymphatics.**—The single tube, indicated at F, is one which, in the actual organisation of the body, diverges and ramifies, like the veins and arteries, into innumerable small tubes, which penetrate all parts of the system. These receive

the lymph and chyle, by a process called *absorption*, from whence these vessels were called *absorbents*. They are now more generally denominated *lymphatics*. The single tube F, into which these numerous lymphatics finally coalesce, and through which their contents are discharged into the vein which enters the right auricle of the heart, is called the *thoracic duct*.

The liquid discharged into the veins as they approach the heart, has been called from its colour *white blood*. Of its components, the *lymph* is a colourless and transparent liquid, like water, while the *chyle* is an opaque white liquid, like milk. Hence, those lymphatic tubes which conduct chyle chiefly or solely, have been sometimes called *lacteals*.

454. **Internal Structure of the Heart.**—In fig. 311 is represented a theoretical section of the heart, supposed to be made by a vertical plane, parallel to the breast and back, and to be viewed from the front ; the right side of the figure being consequently the left of the heart, and *vice versâ*.

It will be perceived that the internal structure, being hollow, is divided into four chambers by one vertical partition, and by two which are nearly horizontal, but a little inclined one to the other, so as to form a very obtuse angle.

While the vertical partition is an absolute wall, dividing the heart into two independent compartments, the two horizontal partitions have valves, both of which open downwards, so that while any pressure from above will open them, making a free communication between the upper and lower compartments, any pressure from below will close them, so as to render the two compartments separate. The names of the principal parts are so indicated on the figure, that it would be superfluous, after what has been already explained, to elucidate them further. It may, however, be observed, that both the auricles and the ventricles are constituted by powerful muscles, by the alternate contraction and relaxation of which the blood, with which the several compartments are filled, is propelled from the auricles to the ventricles, from the ventricles to the arteries, and thence through the other parts of the system.

455. **Course of the Blood.**—The embouchure of the aorta being placed at the upper and inner corner of the left ventricle, the tube passing upwards is bent into the form of a shepherd's crook, and passes downwards behind the heart, and between

it and the spinal column. The two pulmonary veins which proceed from each lung, right and left, coalescing before arriving at the heart, have their embouchures at the internal and external corners of the left auricle. The blood flowing in through these, fills that auricle, and, passing then through the mitral valve into the left ventricle, issues thence through the aorta, and is distributed through the arteries.

456. **Valves of the Heart.**—The blood which returns through the veins arrives at the right auricle by two large veins, called the upper and lower hollow veins, as will be seen in the figure. It issues from the right auricle through the valve between that and the right ventricle, called the *tricuspid valve*, and from the right ventricle it passes, at the upper and inner corner, into the common trunk of the right and left pulmonary arteries, which diverge one from the other immediately under the bend of the aorta.

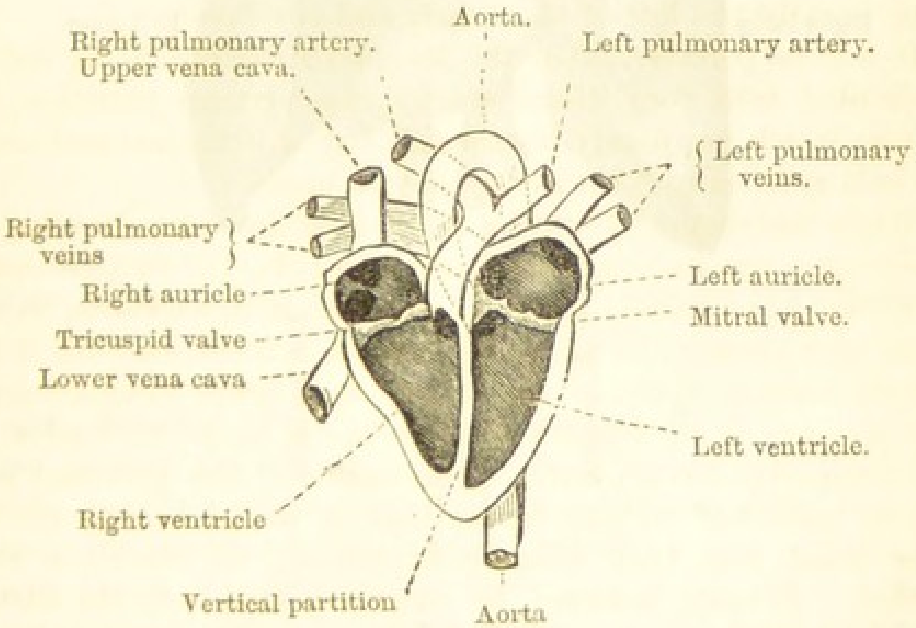


Fig. 311.

THEORETICAL SECTION OF THE HEART, SUPPOSED TO BE SEEN FROM THE FRONT.

457. **Position of Heart and Lungs.**—The actual position of the heart, and the principal veins and arteries issuing from it, with relation to the lungs, is shown in fig. 312, the names of the several parts being indicated. The lungs are represented as having been pushed to each side, so as to show the heart and vessels more distinctly.

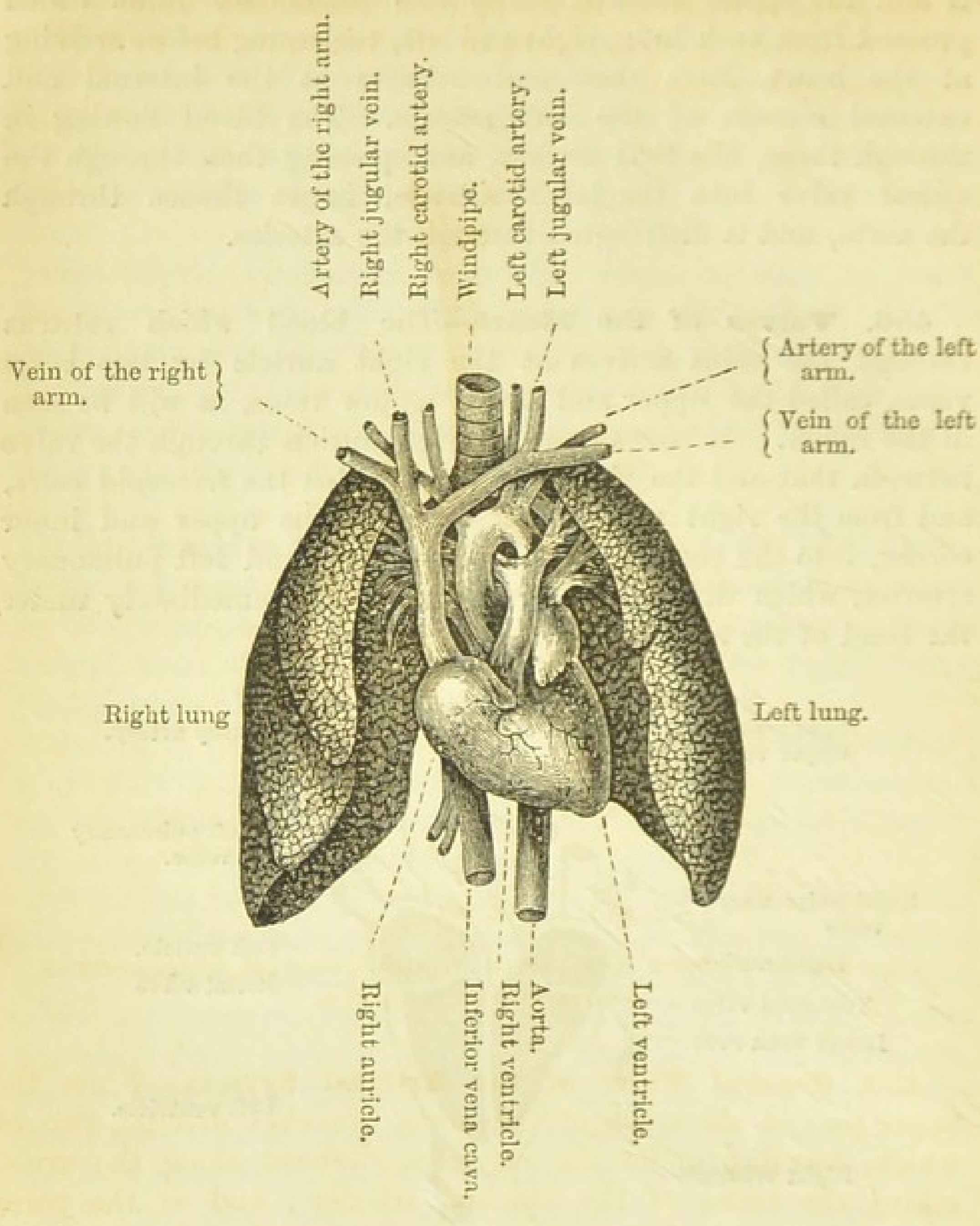


Fig. 312.

FRONT VIEW OF THE HEART AND LUNGS.

458. **Bronchial Tubes.**—The form of the windpipe and its appendages, by which the air is distributed through the lungs, is represented in fig. 313. The vertical part, *a*, is the windpipe, or trachea, properly so called, and the branches which diverge from it right and left, near the upper part of the lungs, are called *bronchial tubes*. These diverge lower down and within the lungs into innumerable minute ramifications, as shown at *e*. One

of the lungs is removed in the figure, to show these ramifications which terminate in the air-cells of the lungs, as the roots of a tree enter the ground.

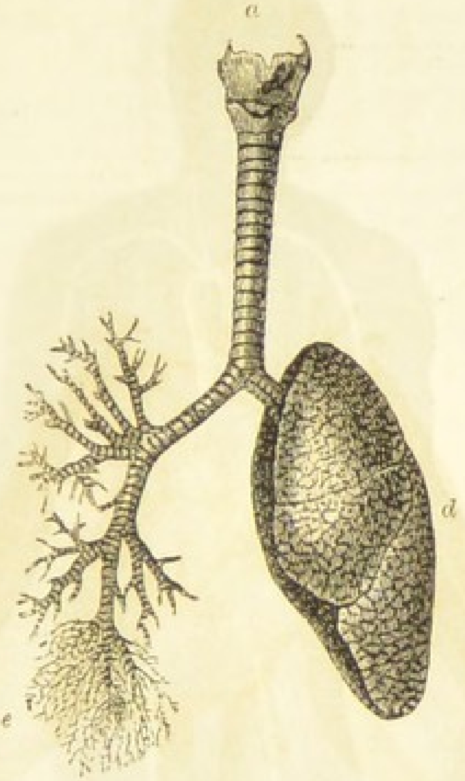


Fig. 313.

VIEW OF THE WINDPIPE AND BRONCHIAL TUBES, SHOWING THEIR POSITION RELATIVELY TO THE LUNGS.

459. **General View of the Arterial System.**—From the upper part of the crook of the aorta branches diverge, two of which, bending under the clavicles, descend along the arms, taking the name of the brachial arteries; and at the point where the aorta descends towards the navel, other branches diverge right and left, descending along the legs, where they take the name of femoral arteries. There are numerous other ramifications, as shown in the general illustration of the arterial system given in fig. 314, where the names of the principal arteries are indicated.

460. **Illustrative Diagrams of the Valves.**—The mechanism of the valves of the heart, which, as must be evident, play a part of capital importance in the circulating apparatus, will be

more clearly comprehended by the illustrative diagram, fig. 315.

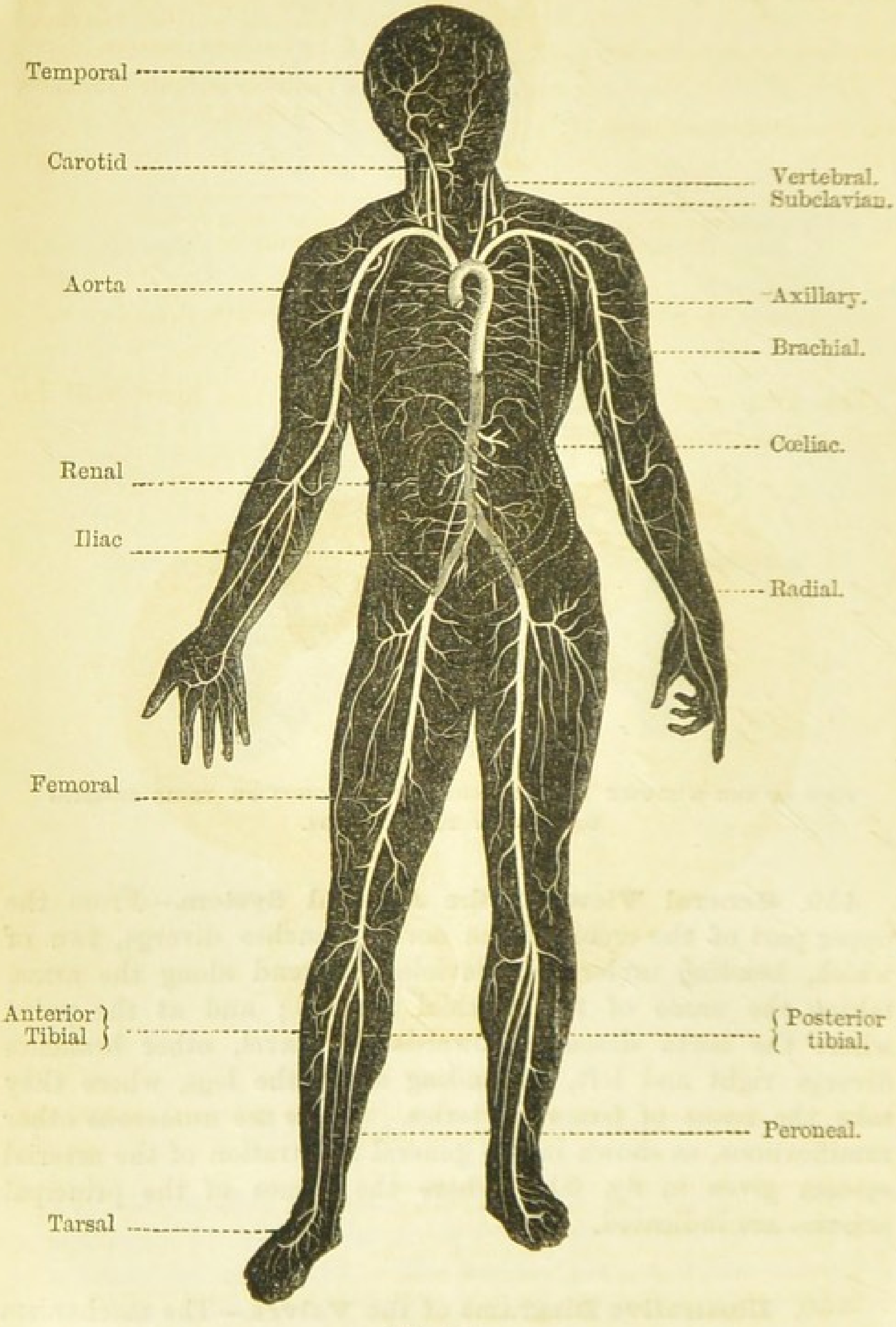


Fig. 314.

THEORETICAL DIAGRAM OF THE ARTERIES AND THEIR RAMIFICATIONS.

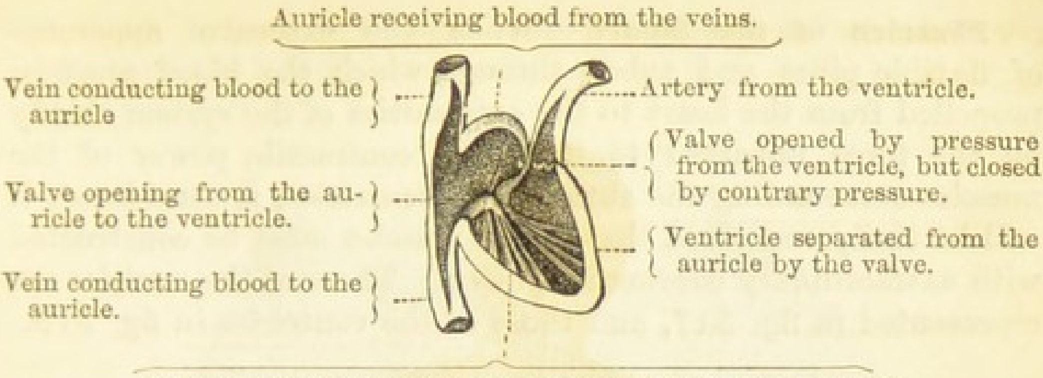


Fig. 315.

THEORETICAL SECTION TO EXPLAIN THE MECHANISM OF THE VALVES OF THE HEART.

The form and structure of the valves of the heart will be further illustrated by the diagram in fig. 316.

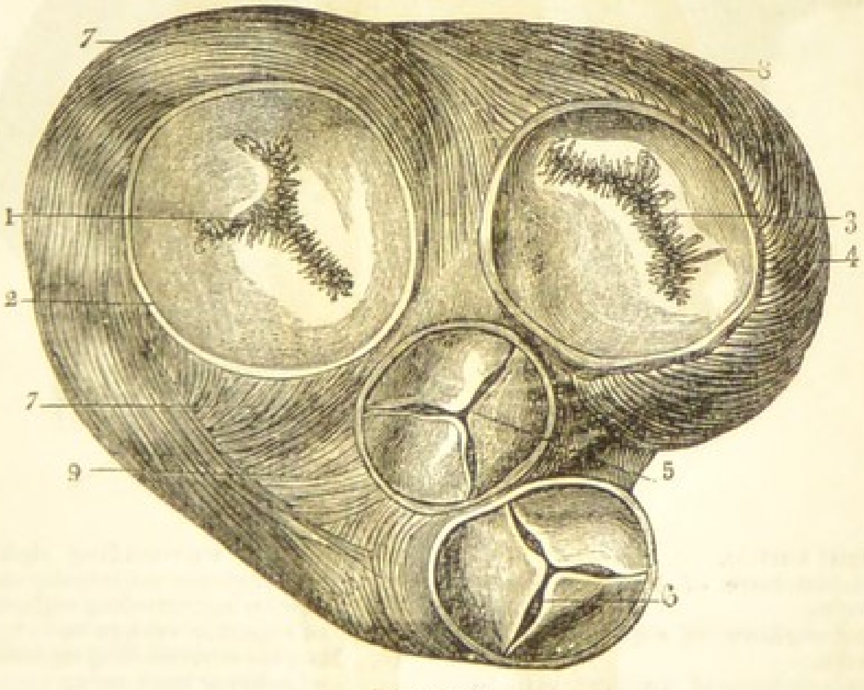


Fig. 316.*

SECTION OF THE HEART MADE BY A PLANE PASSING THROUGH THE VALVES, THE AURICLES BEING REMOVED.

1. Tricuspid valve leading to right ventricle.
2. Fibrous ring surrounding tricuspid valve.
3. Mitral valve leading to left ventricle.
4. Fibrous ring surrounding the mitral valve.
5. Three valves leading from ventricle to aorta.
6. Three valves leading from the right ventricle to the pulmonary artery.
7. Muscles of the right auriculo-ventricular zone.
8. Muscles of the left auriculo-ventricular zone.
9. Muscles inserted in the aortic zone.

* Sappey.

Muscles of the Heart.—When the extensive apparatus of flexible pipes and tubes, through which the blood must be propelled from the heart to the extremities of the system chiefly by the force imparted to it by the contractile power of the muscles surrounding the auricles and ventricles, is considered, it will be easily conceived that these muscles must be constructed with extraordinary contractile power. Those of the auricles are represented in fig. 317, and those of the ventricles in fig. 318.

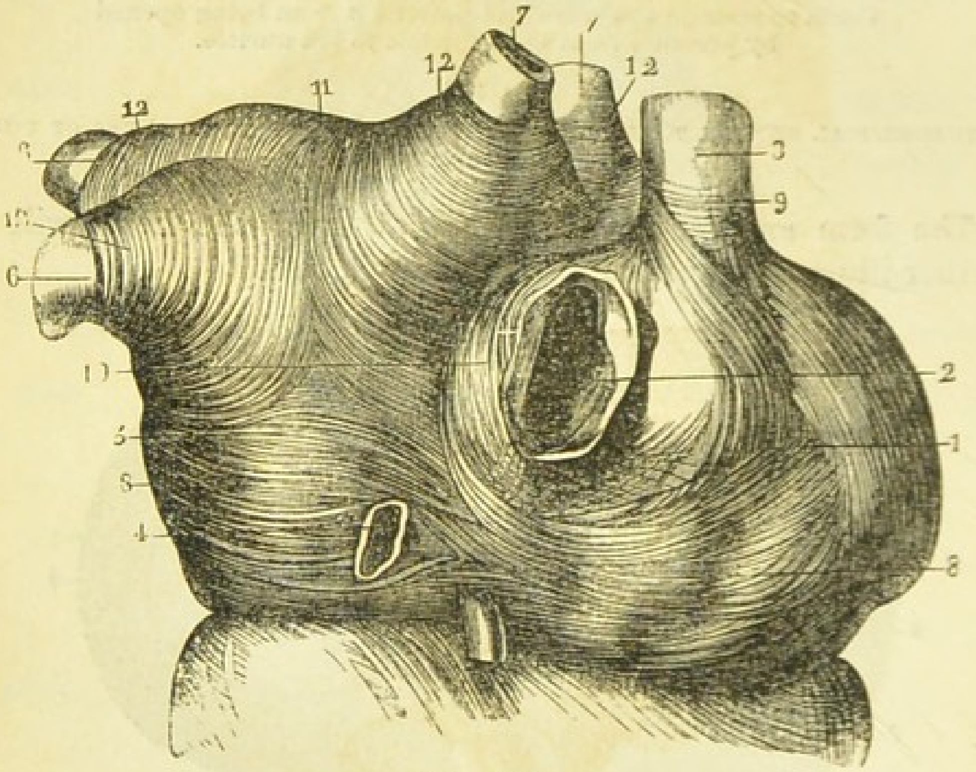


Fig. 317.*

MUSCLES OF THE AURICLES.

1. Right auricle.
2. Embouchure of inferior hollow vein.
3. Embouchure of superior hollow vein.
4. Embouchure of coronary vein in right auricle.
5. Left auricle.
6 6. Left pulmonary veins.
7 7. Right pulmonary veins.
8 8. Muscles surrounding right and left auriculo-ventricular orifices.
9. Muscles surrounding embouchure of superior vena cava.
10. Muscles surrounding embouchure of inferior vena cava.
11. Muscles separating right from left pulmonary veins.
12 12 12 12. Muscles surrounding embouchures of these veins.

461. **Position of the Heart.**—The heart is placed very nearly in the longitudinal axis of the body. Its distance from the point where the neck joins the shoulders, is about one-third of the entire length of the trunk, from which it appears, as remarked by Bichat, that the superior members, and especially

* Sappey.

the head, are under a much more immediate influence of the heart than the inferior and baser parts.

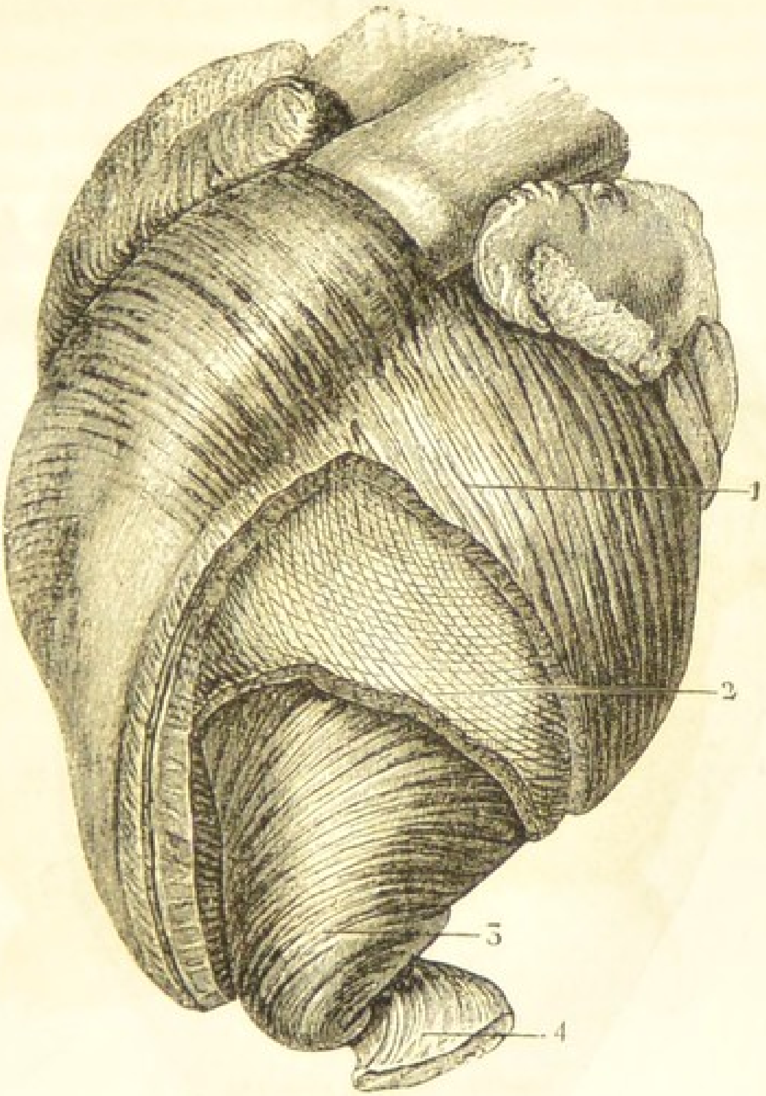


Fig. 318.*

MUSCLES OF THE VENTRICLES.

1. Anterior and superficial muscles directed towards the point of the heart.
2. Muscles of the left ventricle.
3. Anterior and deep-seated muscles rising towards the base of the left ventricle, after having been twisted round the point of the heart.
4. Twisted muscles directed upwards to the left ventricle.

462. **Its Dimensions.**—It has been customary to convey a general notion of the magnitude of the heart by comparing it with the fist. This is, however, a loose and erroneous standard, since the magnitude of the hand varies with the exercise and with the manner in which it is employed.

The average length of the heart may be stated to be about

* Sappey.

four inches, and its circumference where it is largest is a little

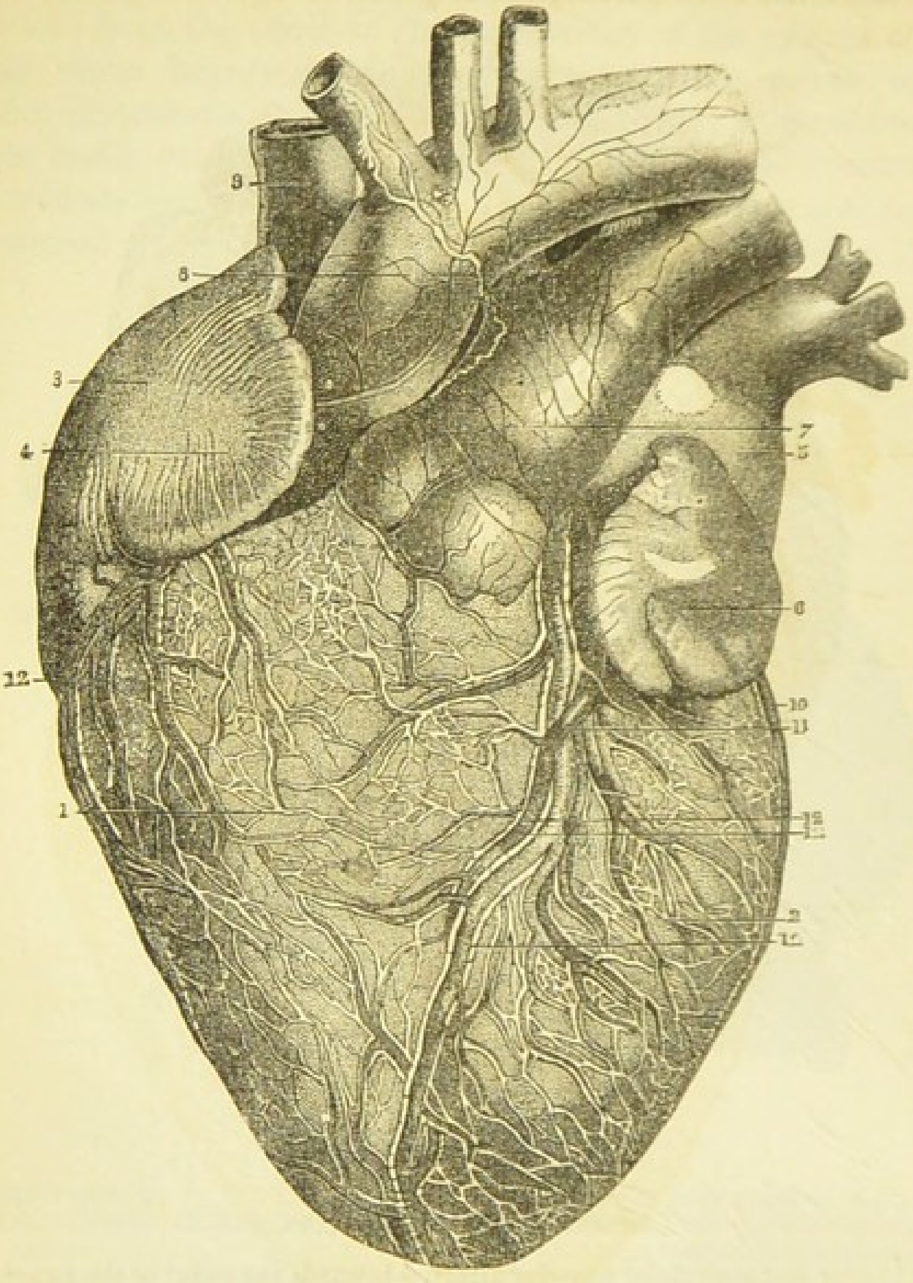


Fig. 319.*

VIEW OF THE HEART SEEN FROM THE FRONT.

Linear dimensions being about seven-eighths of the average magnitude of the heart in an adult.

1. Right ventricle.
2. Left ditto.
3. Right auricle.
4. Appendage of this auricle.
5. Left auricle.
6. Appendage of ditto.
7. Trunk of pulmonary artery.
8. Aorta.
9. Upper vena cava.
10. Anterior coronary artery.
11. Anterior branch of coronary vein.

12 12 12 12. The lymphatic vessels.

less than ten inches. A tolerably correct notion, however, not

* Sappey.

only of its magnitude, but of its form and structure, may be obtained from the engravings of it given in figs. 319, 320, 321, 322, 323.

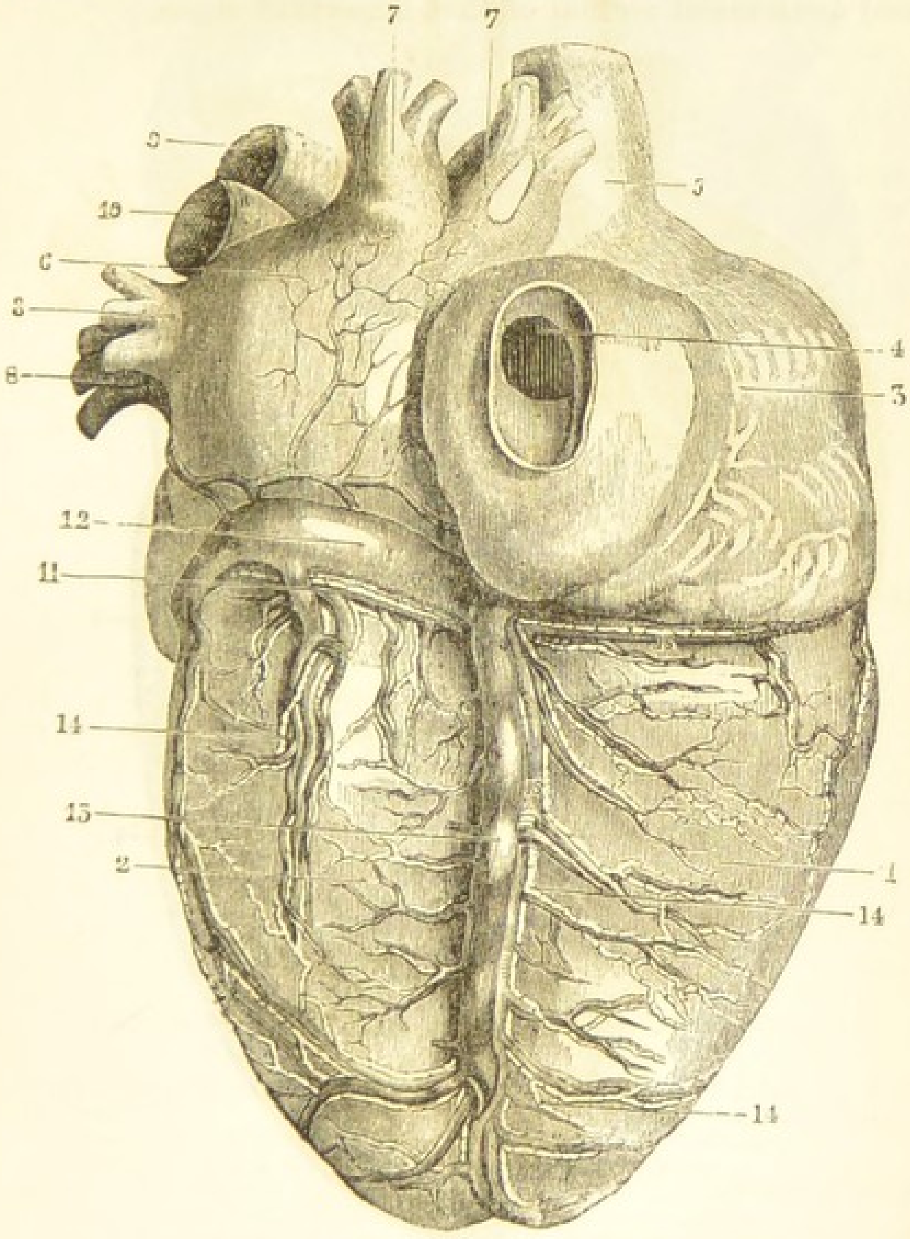


Fig. 320.*

VIEW OF THE HEART SEEN FROM BEHIND.

1. Right ventricle.
2. Left ventricle.
3. Right auricle.
4. Inferior vena cava.
5. Superior vena cava.
6. Left auricle.
7 7. Right pulmonary vein.
8 8. Left pulmonary vein.
9. Aorta.
10. Left branch of pulmonary artery.
11. Auriculo-ventricular branch of anterior coronary artery.
12. Trunk of coronary vein leading to left auricle.
13. Posterior branch of this vein.
14 14 14. Lymphatics.

* Sappey.

Anatomical Section.—The sections of the heart already given being merely theoretical, and made with the exclusive view of explaining its mechanism, it may be useful here to give the real anatomical section of that important organ.

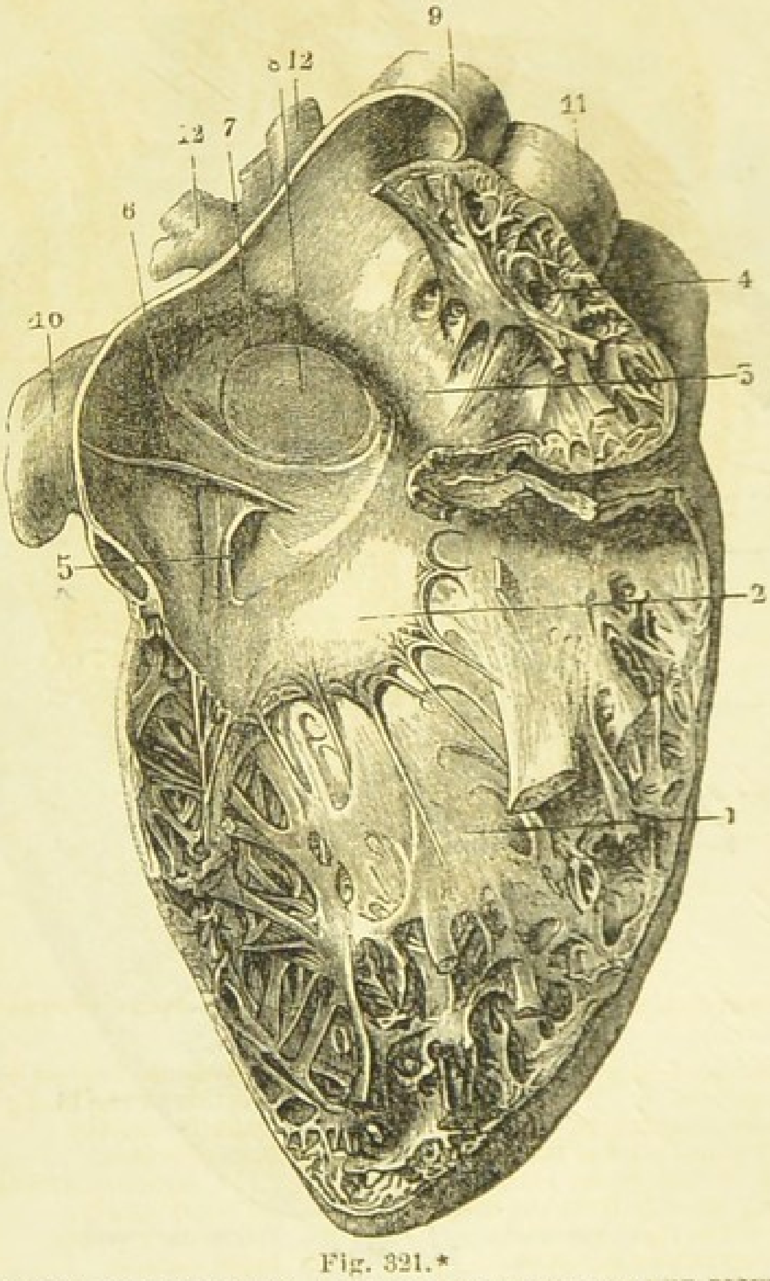


Fig. 321.*

VERTICAL SECTION OF THE HEART, THROUGH THE CAVITY OF THE RIGHT AURICLE.

1. Interior of the right ventricle, showing the fleshy parts which surround it.
2. Part of the tricuspid valve between the right ventricle and auricle.
3. Cavity of the right auricle.
4. Fleshy parts which surround this auricle.
5. Embouchure of the great coronary vein, which brings back the black blood from the tissue of the heart.
6. Valve situate at the embouchure of the lower vena cava.
7 and 8. Oval passage, at the bottom of which is placed an opening, which in the fœtus forms a direct communication between the two auricles.
9. Embouchures of the upper vena cava.
10. Trunk of the lower vena cava.
11. Aorta.
12. 12 Pulmonary veins.

* Sappey.

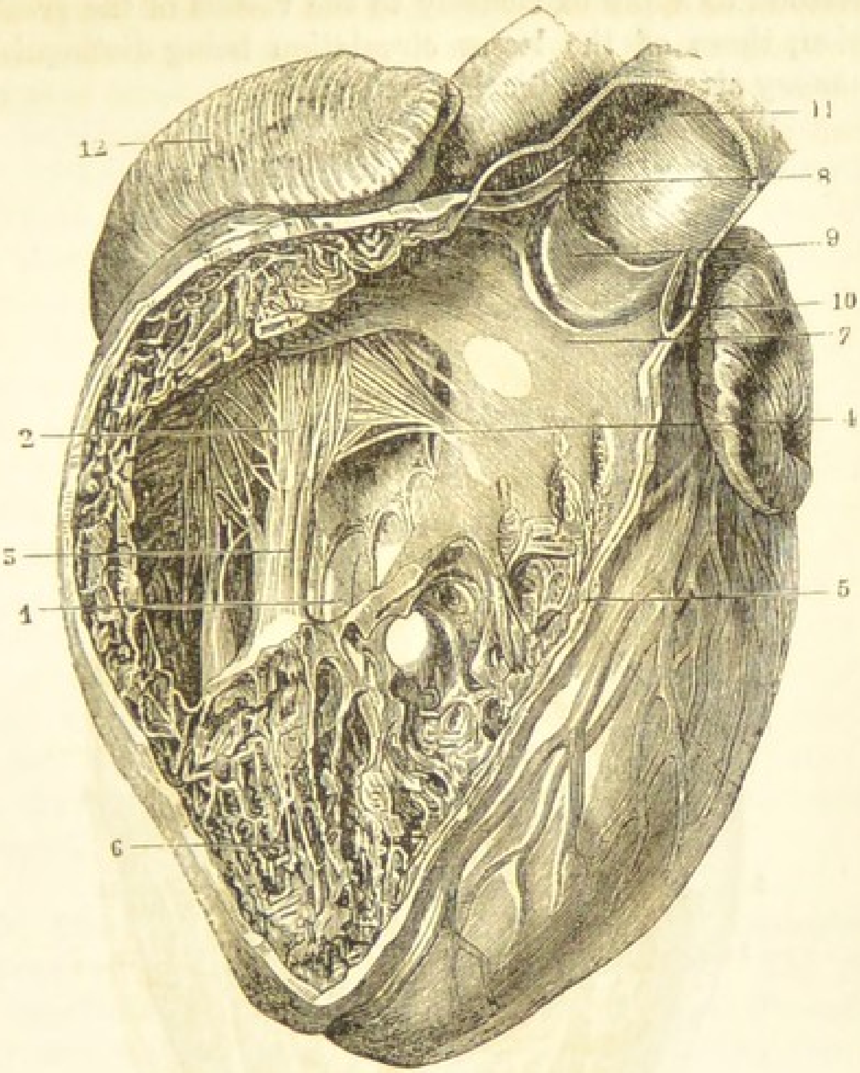


Fig. 322.*

VERTICAL SECTION OF HEART MADE THROUGH RIGHT VENTRICLE.

1. Ventricular cavity.
2. Tricuspid valve.
3. Tendons inserted in the external surface and edge of this valve.
4. Bunch of tendinous cords, originating directly from the internal side of the right ventricle.
5. Interventricular partition.
6. Mesh-work formed by the intersection of the fleshy fibres of the right ventricle.
7. Infundibulum.
8, 9, 10. Sigmoid valves of the pulmonary artery.
11. Pulmonary artery.
12. Right auricle.

463. **Structure and Distribution of the Blood-Vessels.**— The system of vessels in which the great or systemic circulation, as it is sometimes called, is effected, plays a part so important in the economy compared with that of the lesser or pulmonary circulation, that when the terms arteries, capillaries, and veins are used without any qualifying adjunct, they are

* Sappey.

understood to apply exclusively to the vessels of the greater circulation, those of the lesser circulation being distinguished as *pulmonary* arteries, capillaries, and veins.

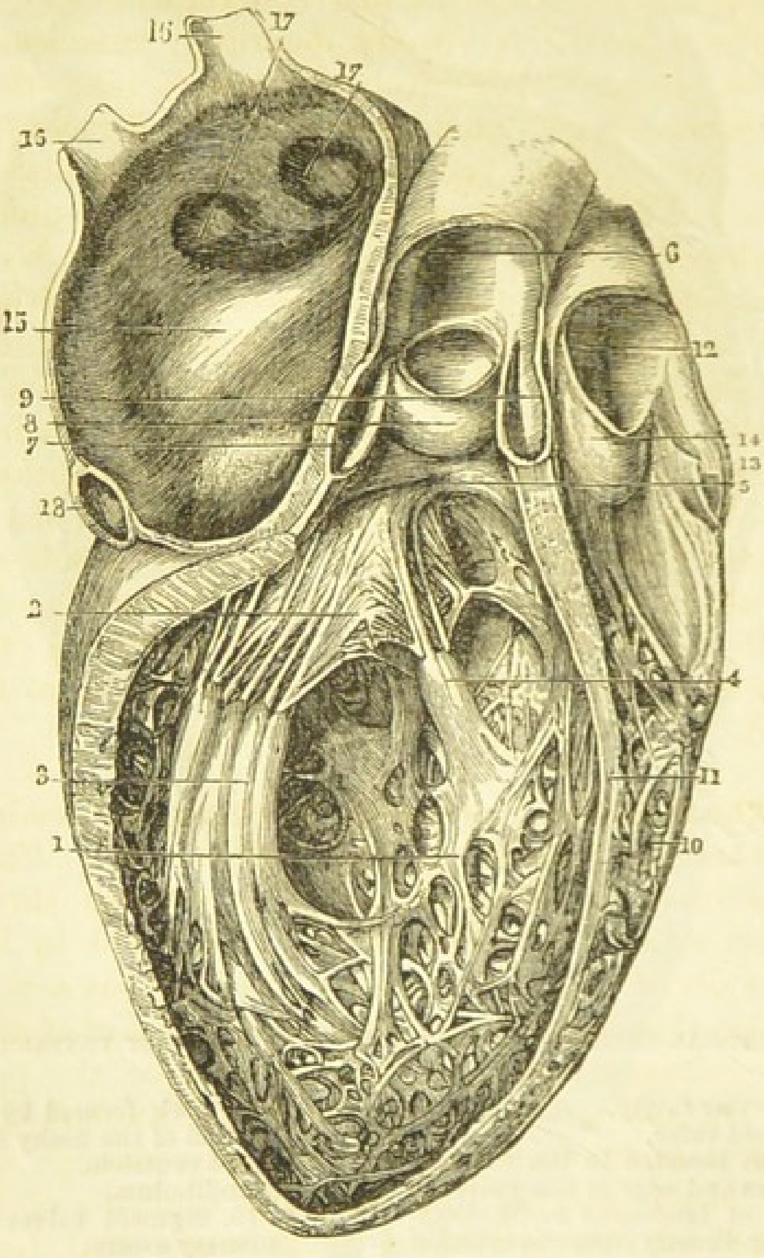


Fig. 323.*

VERTICAL SECTION OF THE HEART THROUGH THE LEFT VENTRICLE AND AURICLE.

1. Left ventricle.
2. Mitral valve.
3. Principal fleshy column of the left side, divided into two bundles, subdivided at their summit.
4. Principal fleshy column of the right side, smaller than the former.
5. Orifice from the ventricle to the aorta.
6. Aorta.
7, 8, 9. The three aortic valves.
10. Right ventricle.
11. Interventricular partition.
12. Pulmonary artery.
13, 14. Its valves.
15. Left auricle.
16, 16. Right pulmonary veins.
17, 17. Their embouchures.
18. Section of the coronary vein going round the left auricle at its posterior part, and arriving at the right auricle.

* Sappey.

464. **Capillaries.**—Although these vessels have received a distinct name, there is no precise line of demarcation in the economy to mark where the arteries terminate and the capillaries begin, or where the capillaries terminate and the veins begin. The arteries, as already described, commencing in a single tube, diverge successively in approaching the organs which they nourish into ramifications more and more multiplied in number, and smaller and smaller in their calibre, until at length they assume that extremely multiplied number and minute calibre to which the name capillaries has been given. In like manner, the veins are necessarily as multiplied and minute as are the capillaries, where the capillaries run into them. Nevertheless, although there be no distinct separation between these classes of vessels, it has been found convenient, in descriptive anatomy, to designate them by distinct appellations. The capillaries have, moreover, a physiological character distinct from those of either the arteries or veins, being the vessels in passing through which, the bright red or nutritive blood is converted into dark red or vitiated blood, and, therefore, the place where the nutritive functions of the blood are more especially discharged.

465. **The Pulmonary or Lesser Circulation.**—Analogous observations are applicable to the pulmonary vessels. The pulmonary capillaries, by which the blood is diffused through the spongy and cellular substance of the lungs, and by ramifying over the walls of the air-vesicles is exposed to the action of the air by which these are inflated, have no exact point of distinction from the pulmonary arteries on one side, or the pulmonary veins on the other, but are nevertheless distinguished by their physiological functions, since it is in passing through them that the dark blood received from the right ventricle of the heart is converted into the red blood which is propelled through the pulmonary veins to the left auricle.

466. **Pulsations of the Heart.**—The alternate states of the ventricles and auricles during their contraction and relaxation are called *systole* and *diastole*, from two Greek words having a like signification. From what has been explained, it will be understood that the systoles of the two auricles are simultaneous and are alternate with those of the ventricles, but the systoles of the auricles do not instantly follow that of the ventricles. Between the systole of the ventricles and that of the auricles the entire

heart is for a moment in a state of repose, or, what is the same, the diastole of both auricles and ventricles has a longer duration than the systole. The mean rate of the pulsations of the heart being about eighty per minute, the duration of one complete pulsation will be three-fourths of a second; and it has been found that the duration of each systole, whether of the auricles or ventricles, is about a quarter of a second, the diastole, therefore, being half a second.

The periodic action of the heart may, therefore, be thus described. The systole of the auricles is performed in the first quarter of a second, during which the ventricles are in diastole. During the next quarter of a second, the ventricles are in systole, and the auricles in diastole, and we find during the third quarter of a second both ventricles and auricles are in diastole. A like series of actions then recommences, and is repeated. If we express the state of systole or contractile action by the sign +, and that of diastole or repose by the sign O, the simultaneous condition of the auricles and ventricles during each complete pulsation of the heart will be represented as follows:

Auricles . . .	+	O	O
Ventricles . .	O	+	O

It appears from this, that the muscles of the heart are in repose during intervals twice as long as those of their action; a circumstance which will render somewhat less wonderful the power in virtue of which this organ maintains its action throughout the longest life. The total duration of the action of these muscles will be only one-third of the total duration of life. During the other two-thirds they are in a state of repose.

467. **The Embouchures of the Pulmonary Veins**, which enter the auricles, are not, like those of the arteries proceeding from the ventricles, supplied with valves, by which the reflux of the blood during the auricular systole would be prevented. That reflux, however, is resisted partly by the contraction of the auricle itself, which, commencing near the embouchures of the veins, presses before it the blood, partially closing these embouchures, and pushing the blood before it nearly in the

same manner as the food in process of digestion is pushed through the intestine. The valves already described between the auricle and the ventricle being large and freely opened, the blood passes directly into the ventricle, exerting no force of reflux upon the embouchures of the pulmonary veins.

The veins leading into the right auricle, are supplied with valves called the Eustachian and coronary valves, which, however, close them but imperfectly ; for the reasons just mentioned, however, there is no reflux.

468. **The Contractile Force of the Cardiac Muscles** must necessarily vary, like all forces in well regulated mechanism, in proportion to the mechanical effect which it is required to produce. Either a deficiency or redundancy of impulsive force would soon produce a derangement of the organ. But from the position of the heart with relation to the lungs on the one hand, and to all the organs of the body to which it propels the nutritive blood on the other, it will be apparent that considerably more force is required to maintain the greater than the lesser circulation ; and, consequently, the power of the muscles which act upon the left auricle and ventricle must be proportionately greater than those which act upon the right. Various means have accordingly been suggested by which the comparative power of these muscles can be estimated ; the most simple and practicable of which is the comparison of the weight of the two sets of muscles. By such a comparison, it has been ascertained that the weight of the muscles which act upon the left side of the heart is twice that of the muscles which act upon the right side. This proportion is found to be sensibly the same in man, the horse, the sheep, the dog, the cat, the rabbit and the pig. It is further remarkable, that this predominance of weight is found to prevail especially in the ventricles, a result which is consistent with the fact that the ventricles are the more immediate propelling agents. The left ventricle, therefore, having twice the weight of the right ventricle, has consequently twice the propelling power ; and the greater circulation, accordingly, is maintained by a moving power greater than that which maintains the lesser circulation in the proportion of their respective resistances.

469. **The Beating of the Heart** is a phenomenon which has not been fully and satisfactorily explained by physiologists.

It is certain, however, that whatever be its cause, the organ, being fixed at its upper part in the region of the auricles, is free in the lower part, which is the region of the ventricles; and that the effect familiar to every one as the beating of the heart is produced by alternate motion forwards and backwards of the lower part of the organ, which takes place simultaneously with the ventricular systole and diastole.

470. **Torsion of the Heart.**—But, besides this forward motion, it has been ascertained that the heart has also an alternate motion of torsion round its vertical axis; so that, if it were denuded and exposed to view in the living subject, it would present itself from moment to moment under different aspects to the eye, just as a body would which turns round vertically, with an alternate motion right and left. At the moment of the ventricular systole the heart turns slightly on its axis from left to right; and during the diastole, turning in the contrary direction, resumes its first position. This movement of torsion is not extended to all parts of the heart, the auricular region having no share in it. The torsion commences in the horizontal plane, passing through the valves, where it is scarcely perceptible, and increases gradually from that to the point where it is greatest.

This movement of torsion involves also a slight forward projection of the point of the heart, which must not, however, be confounded with the much more considerable movement of the organ which produces the beating.

471. **The Force with which the Blood is propelled** through the arteries has been measured by direct experiment, by putting it in communication with a mercurial gauge inserted in an opening made in the aorta for the purpose. In this manner, it was shown to be in equilibrium with a column of six inches of mercury.

Blood being about fifteen times lighter than mercury, it follows that if a siphon-gauge be inserted into an artery, a column of blood would rise in the vertical length to the height of about seven and a half feet, at which it would be sustained by the tension of the fluid contained in the arteries.

472. **The Structure of the Arteries.**—The action of the muscles and valves of the heart would lead to the supposition

that the movement of the blood in circulation must be intermitting, and not continuous. It might be inferred, that during each systole, the blood would be pushed forward through the arteries, capillaries and veins ; and that, during each diastole the motion would be suspended.

This is, however, not the case in the animal economy, the motion of the blood being continuous and not intermitting. Though continuous, it is not strictly uniform, being accelerated and retarded by the alternate action of the ventricular muscles. This continuous movement of the blood is produced by a provision in the structure of the blood-vessels.

The arteries are flexible tubes composed of three coatings, the innermost or first of which is a thin and extremely smooth membrane which lines the ventricle, and is adapted to allow free flow to the current of the blood. This tube is sheathed in another, consisting of a thick, yellowish, highly elastic substance, of annular structure, and of involuntary muscular fibres, the rings composing it having their planes at right angles to the direction of the artery. This is again invested with an external coating of dense and close cellular texture. Thus, the structure of the arteries may be said to resemble that of the hose of a fire-engine.

The arteries thus constructed are endowed at once with elasticity and muscular contractility, both of which qualities have an important share in maintaining the circulation.

During the ventricular systole, the blood is propelled with great force into the arteries, which, in virtue of their elasticity, yield to this momentary pressure, and are augmented in their calibre. During the ensuing diastole, when the valve between the ventricle and aorta called the sigmoid valve is shut, the blood in the arteries, no longer receiving any impulsive force from the heart, would cease to move, so that the circulation, instead of being continuous, would be intermittent. This effect, however, is prevented by the elasticity of the coats of the arteries, which re-act upon the blood that has distended them, so as to urge it in one direction or the other ; but since its reflux to the heart is prevented by the sigmoid valve, which opens only to the arteries, the blood must be pressed by the elasticity of the arterial coats towards the organs which it is intended to nourish.

The elasticity of the arteries therefore acts in this case precisely in the same manner as does a fly-wheel attached to any machine propelled by an intermitting power. The motive power

exerted by the ventricle in its systole is expended partly in propelling the blood into and through the arteries, and partly in distending the elastic coats of the arteries. During the succeeding diastole, the latter part of the moving force is given back to the blood by the compression produced in virtue of the elasticity of the arteries, and the blood is accordingly urged forward through the arterial system during the suspension of the moving power of the heart, just as a machine continues to be driven by the inertia of the fly-wheel during the intermission of the power which drives it.

If it might be supposed that the force of the heart during the systole is equally shared between the blood and the coats of the heart which it distends, then the movement of the blood would be perfectly uniform, notwithstanding the intermitting action of the ventricle. That this equality of action, however, does not obtain, is proved by experiments in which the force of the blood is directly measured; from which it appears, that during each ventricular systole, the column of mercury supported by the blood is raised about a 12th part of its entire height.

But, besides the elasticity of the arteries, which may be regarded as a passive force called into action by and depending on that of the ventricular systole, the arteries have been stated by many physiologists to possess muscular contractility, in virtue of which the blood is constantly propelled forwards quite independently of any action of the heart. It will therefore be apparent that the circulating mechanism is not to be regarded as being analogous to an hydraulic system with a moving power at one end only, but rather to an hydraulic apparatus, in which, besides the primitive moving power by which the liquid is propelled into the tubes, the tubes themselves throughout their entire length exercise a mechanical pressure on the included liquid, to which effect is given by the reaction of the sigmoid valve preventing the reflux of the blood, which is consequently driven forward towards the capillaries.

One of the effects which render manifest this contractile force of the arteries is the fact, that after death, when the action of the heart ceases, all the blood contained in the arteries is driven forward into the veins.

473. **The Pulse** is nothing more than the alternate distension and contraction of an artery which takes place during the systole and diastole of the ventricle.

474. **The Capillaries.**—These vessels, as already explained, are the minute canals which traverse the organs and are interposed between the arteries and the veins, receiving the blood from the former and discharging it into the latter. They are the immediate theatre of nutrition, since it is in them and through their coats that the blood imparts nourishment to the organs, and becomes impregnated on the other hand with matter which the organs reject. In this process the blood undergoes an important change in its physical properties, being converted in its colour from a bright vermilion red to a dark brown red, and losing altogether its nutritive functions. Having undergone this change, it is discharged by the capillaries into the veins, and through them flows back to the right side of the heart.

The capillaries, like the arteries, are endowed at once with elasticity and contractility, and possess the latter property even in a greater degree than the arteries. If the blood-corpuscles were perfectly solid and inelastic, it is evident that, as they must pass through the capillaries, their magnitude would impose a minor limit upon the calibre of these vessels, since a corpuscle cannot pass through a tube whose calibre is less than its own diameter. But, since the corpuscles are more or less elastic or compressible, they sometimes by elongating themselves force their way through tubes whose calibre is a little less than their own diameter. The most minute capillaries have a calibre measuring about the 4000th of an inch, while the calibre of the largest of these vessels measures the 2500th part of an inch. The capillaries which pervade any given organ are of uniform calibre, but those which pervade some organs are of greater calibre than those which pervade others. The largest capillaries are those which run through the bones and mucous membranes, and the most minute those which pervade the nervous system, the lungs, the skin, and the muscles.

The rate at which the blood moves through the vessels must decrease in proportion as the collective magnitude of the transverse sections of the vessels increases, just as the current of a river is diminished in speed as its bed is enlarged, or as the collective section of the branches which form its delta is augmented. Now, it is found that the collective section of the ramification of the arteries is greater than that of their trunks, and the collective section of the capillaries is greater than that of the arteries at the point where the branches of the latter

enter them. The current of the blood, therefore, most rapid in issuing from the heart, continually decreases in speed as it approaches the capillaries, through which it passes at a still slower rate, in proportion to the increased magnitude of their collective transverse sections.

This effect is quite in accordance with the physiological functions of the capillaries, the retardation of the blood giving the time necessary for the production of those physical changes which necessarily accompany the discharge of its nutritive functions.

Since the vascular system is always completely filled with liquid blood, and since the blood, like all other liquids, is inelastic and incompressible, it follows obviously that the quantity of blood propelled into the arteries by each ventricular systole is exactly equal to that which flows during each pulsation of the heart from the arteries into the capillaries. But, since the blood thus propelled from the heart is distributed among the capillaries of various parts of the body, and since the capillary vessels are subject, from various causes, to occasional obstruction, a redundancy of blood will sometimes be discharged into certain capillaries, others being at the same time deprived of a corresponding quantity. Among the causes which produce such local variations of the circulation, are the nervous actions which attend mental emotions. Thus, shame or anger, by compressing certain capillaries, propel the blood in undue quantity through those of the cheeks, producing the blush of shame, and the suffused red of anger. On the other hand, the emotions of terror and despair produce obstructions which are attended with the pallor that indicates these emotions.

475. **The Veins**, like the arteries, are flexible tubes, similar in their internal and external coating; but the intermediate envelope of annular structure is replaced by a thin coating of longitudinal, loose, and extensible fibres.

One of the consequences of this difference of structure is, that an artery, even though empty, as it is after death, preserves its tubular form, while an empty vein will collapse.

The veins are elastic and contractile, but much less so than the arteries. If a vein be temporarily distended, it will, when relieved, recover its former calibre, but if the distension be long continued, the enlargement will be permanent. This permanent enlargement of the veins is very common with aged persons.

The pressure of the blood in the veins is much less than in

the arteries. Being measured by means similar to those already described, it is found to be balanced by a column of mercury measuring six-tenths of an inch, while the pressure of blood in the arteries balances a column of six inches. The tension, however, of blood in the veins is subject to much variation. Thus, M. Mogk found that in the jugular vein it balanced half-an-inch of mercury ; in the brachial vein, six-tenths of an inch ; and in the crural, nearly an inch.

476. **The Valves of the Veins.**—Considering the great length

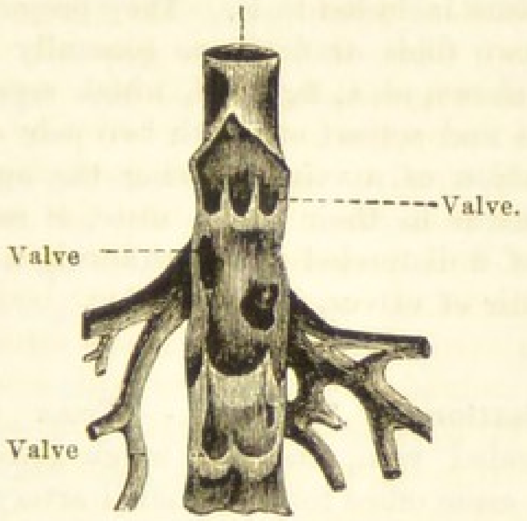


Fig. 324.

A VEIN, SHOWING THE VALVES WHICH RESIST THE REFLUX OF THE BLOOD TO THE CAPILLARIES.

and numerous and complicated ramifications of the arteries, it

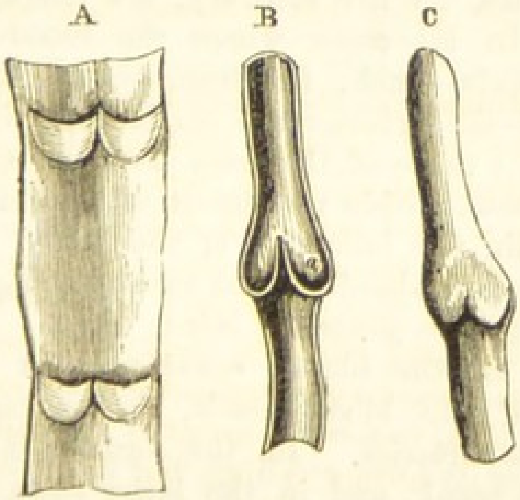


Fig. 325.

will be evident that the single point of reaction opposed to the

power propelling the body by the sigmoid valve, would have but imperfect efficiency ; and this efficiency would be still less when the propulsion of the blood back to the veins is considered. This imperfection is accordingly foreseen, and removed by the provision of a series of valves called, from their form, semi-lunar valves, in the veins, all of which, opening towards the heart, prevent the reflux of the blood towards the capillaries. A vein cut open so as to show the form of these valves, is represented in fig. 324. These valves are formed by folds of the lining membrane of the vein, and are strengthened by some fibro-cellular tissue included in it. They project obliquely into the vein, and two folds or flaps are generally placed opposite each other, as shown at A, fig. 325, which represents a part of a vein laid open and spread out with two pair of valves. The longitudinal section of a vein, showing the opposition of the edges of the valves in their closed state, is represented at B ; and a portion of a distended vein, exhibiting a swelling in the situation of a pair of valves, is shown at C.

477. **Cicatrisation of Wounds.** — From the facility of healing a wounded vein, and the much greater difficulty of performing the same office for a wounded artery, it is obviously desirable that the latter class of vessels should be more especially protected from injury by external causes. Nature has accordingly placed them in such situations in the economy of the system as to afford them in all cases the greatest amount of protection. While a large portion of the veins are superficial, the arteries, on the contrary, are deeply lodged within the surface. In all cases where the blood-vessels must be carried over joints—such, for example, as the knees, elbows, and shoulders—the arteries are conducted within the bend of the articulation ; those of the arms passing within the arm-pit ; those of the elbow, within the inflection of that joint, and those of the leg within the inflection of the knee ; while the vessels which pass over the shoulder, the external angle of the elbow, and the knee-cap, are generally veins.

The current of the blood, considered in relation to the ramifications of the blood-vessels, is contrary in the veins to that in the arteries. In the former, it flows from the branches to the trunk, and in the latter from the trunk to the branches. The circulation taken collectively has been compared to a tree, the extreme ramifications of whose branches

should be brought into connection with the extreme ramifications of its roots.

478. **The Circulation of the Blood is rendered visible in the Microscope** by extending any thin, semi-transparent membrane of a living animal before the object-glass of the instrument, and throwing a sufficiently strong light behind it. The arterial and venous currents of the blood will then be distinctly seen by the aid of a moderate magnifying power. The best method of making this experiment is by means of the web part of the foot of a frog, or of the thinnest part of its tongue.

In figure 326 the circulation in the blood-vessels of the foot of the animal is thus shown, where *a a* are arteries in which the blood is seen flowing, as indicated by the arrows, from the trunks to the branches, and *v v*, veins, in which it flows from the branches to the trunk, the capillaries being represented by dotted lines.

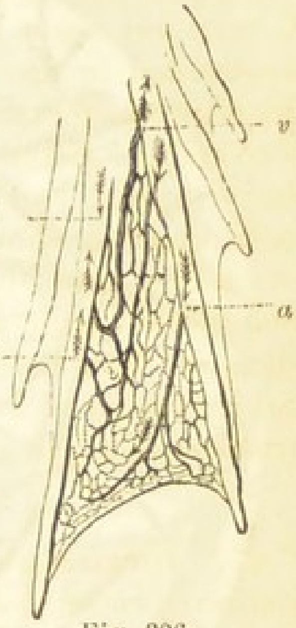


Fig. 326.

479. **Daguerreotypes of the Circulation** in the tongue of a frog were produced by Messrs. Donné and Foucault, in the same manner as already described in the case of the corpuscles of the blood. We have, by the permission of these gentlemen, reproduced, in fig. 327, one of these.

When the tongue is viewed, placing a light behind it, with a simple magnifying glass having a power no greater than fifteen or twenty, the observer will be filled with astonishment at the magnificence of the spectacle. To imagine a geographical map to become suddenly animated, by their proper motions being imparted to all the rivers delineated upon it, with their tributaries and affluents, from their fountains to their embouchures, would afford a most imperfect idea of this object, in which are rendered plainly visible, not only the motion of the blood through the great arterial trunks, and thence through all their branches and ramifications to the capillaries, but also its complicated vorticular motions in the glands, its return through the smaller ramifications of the veins to the larger trunk veins, and its departure thence *en route* for the heart. Such is the astonishing spectacle, circumscribed within a circle having the diameter of the 120th of an inch, magnified, however, 400 times in its linear, and therefore 160000 times in its superficial dimensions.

The arteries are distinguishable from the veins very readily, by observing the direction in which the blood flows, its velocity, and their comparative calibre. In the arteries the blood flows from the trunk to the branches ;

the arrows show its course passing into the principal branches, 1, 2, and 3, from which it flows into all the smaller arterial ramifications. The course of the blood in the veins, on the contrary, is from the branches to the trunk.

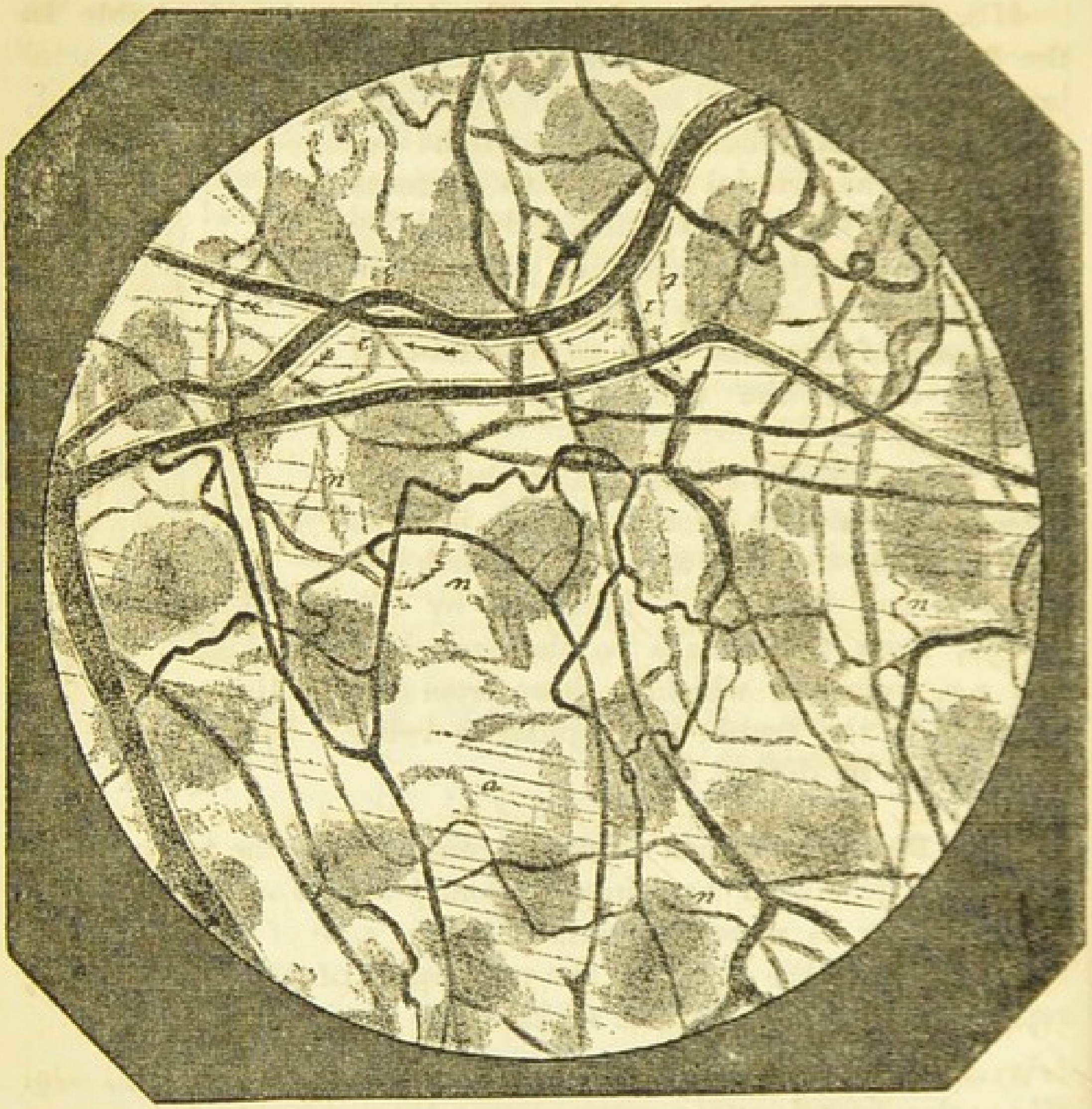


Fig. 327.

MICROSCOPIC DAGUERREOTYPE OF PART OF THE TONGUE OF A FROG, THE 120TH OF AN INCH IN DIAMETER.

The greater arteries are accompanied by a greyish flexible cord, which can be perceived, but not without some attention : it passes along the sides of the artery : this cord is only a nerve.

As the ramifications of the arteries are multiplied in number they are diminished in calibre, and merge at length in the capillaries, from which they are scarcely distinguishable, the latter being equally indistinguishable from the smaller veins. As the capillary vessels diminish in diameter, the red corpuscles at length so completely fill them, that they can only move in them one by one, and they can be thus seen following one another at perceptible intervals. If the microscope be directed to that part of the edge of the tongue, which is within the limits of the hole made in the cork on which the tongue is extended, the blood can be traced in its

course to the extreme arteries, and thence from the smaller to the larger veins on its return to the heart.

The vascular system of the tongue appears traced upon a greyish semi-transparent ground, on which a multitude of fine fibres, *v v*, are seen extended in different directions; these, existing at different depths within the thickness of the tongue, appear superposed and interlaced ; these fibres belong to the muscle of the organ, and their characteristic action is rendered evident under the microscope by their alternate contraction and extension. A number of greyish spots, somewhat round in their outline and a little more opaque than the neighbouring parts, appear scattered through the tongue : these spots belong to the mucous membrane, and are in fact the mucous follicles of the tongue, the little glands in which is secreted the viscous humour which coats in such abundance the tongue of the frog ; and we accordingly find that if it be wiped off, it will be almost immediately reproduced. They are the theatres of a surprisingly complicated and active blood-motion. The sanguineous fluid enters them at one side, generally by a single small artery, rarely by two ; and following the course of this artery, it pursues a nodulated path, resembling the form of a bow of ribbon, or the figure 8, and issues from them at a point opposite to that it entered. The organs of which we speak, says Dr. Donné, having a certain thickness, we cannot always see at once the entrance and departure of the blood, the point of its departure being often in a plane inferior or superior to that of its entrance, and the two points not being, therefore, at the same time in focus. But in any case, nothing can be more curious or more profoundly interesting than the vortices of rapid circulation, thus exhibited, in a space so circumscribed and within the limits of an organ, which is evidently one of secretion.

480. **General Ramifications of the Blood-vessels.**—As has been already observed, the arteries and veins distribute themselves in innumerable ramifications from the heart through all parts of the body. They spread through the muscles, amid whose fibres they ramify, and penetrate the very bones, whose structure is filled with them. We have already given, in fig. 314, a general view of the manner in which the arteries ramify ; and the veins differ from the arrangement there represented only in this, that while the larger arteries are generally confined to certain depths within the surface, veins of large size ramify superficially also in immense numbers, so as to be rendered visible in various parts of the body as blue lines seen through the semi-transparent texture of the epidermis or superficial skin.

481. It may be here stated that the skin, properly so called, is that covering having a very sensible thickness, which is taken between the fingers when we pinch the surface of the body, as, for example, the back of the hand or the neck. This consists of two distinct parts ; the inner and thicker part, called the true skin, *cutis*, or *derma*, a Greek

word signifying the skin, and the superficial or thinner part called the *cuticle*, *epidermis*, or covering of the skin, from a Greek word ἐπὶ (*epi*), signifying *upon* or *over*. The membrane thus named is that which is raised and separated from the derma by a blister.

Although it would be impossible to give, in a work like the present, figures which would convey any notion of the local distribution of the blood-vessels through the body, other than the general representation of the arterial system given in fig.

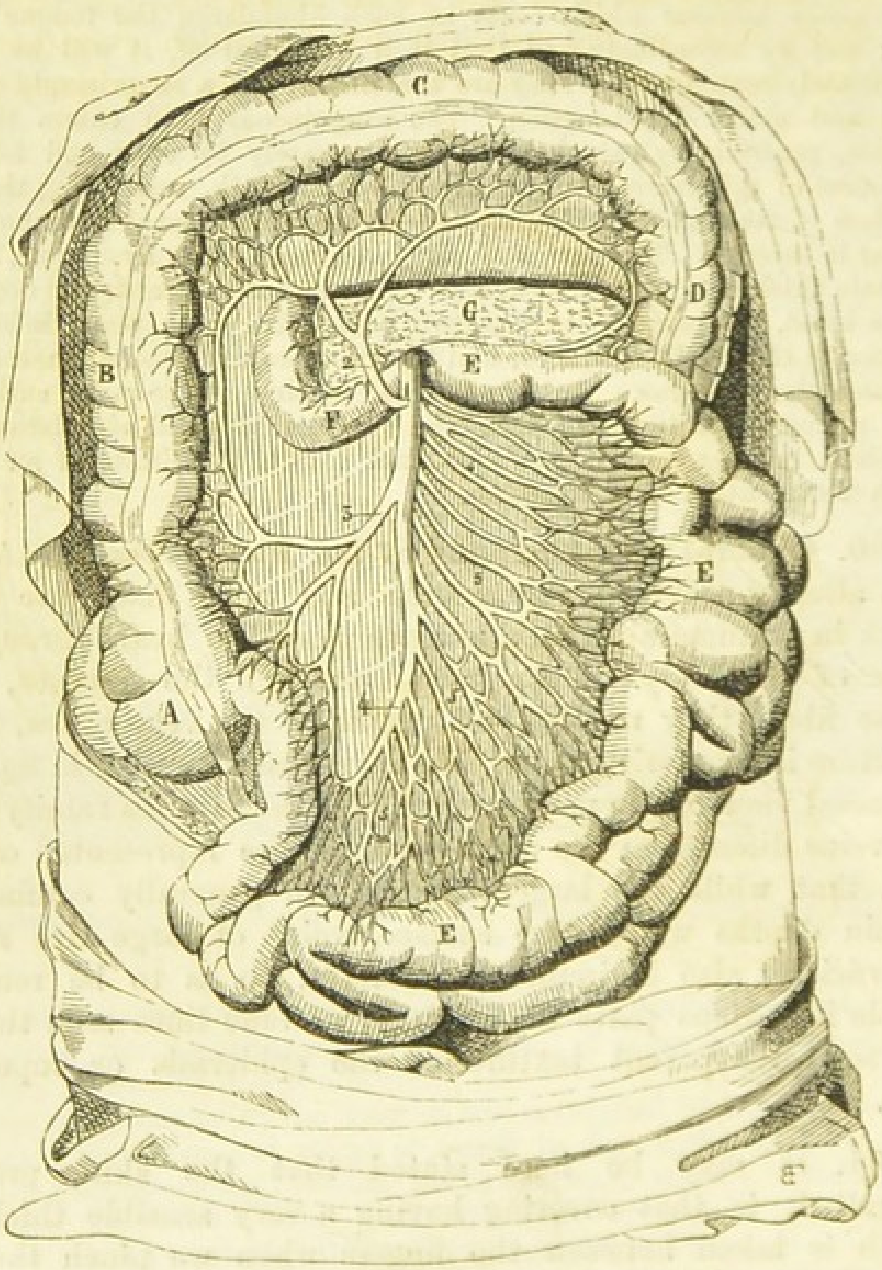


Fig. 328.

314, it may, nevertheless be interesting to readers who are not professionally medical, to see the wonderful structure of the

vascular system in some of the principal parts of the human economy.

482. **Blood-vessels of the Mesentery.**—In fig. 328 are represented the trunk (1), and the innumerable ramifications and anastomoses (2, 3, 4, 5) of the artery which spreads over the *mesentery*, a membranous structure connected with the intestines.

483. **Blood-vessels of the Head and Face.**—In figure 329 are shown some of the principal arteries which overspread the head and face, to each of which anatomists have assigned proper names.

Fig. 329.*

The external carotid trunk, which passes up on the inner

* Sappey.

side of the jaw, is shown at 1; the branches which overspread the head at 2; the temporal ramifications at 3 and 4; the arteries

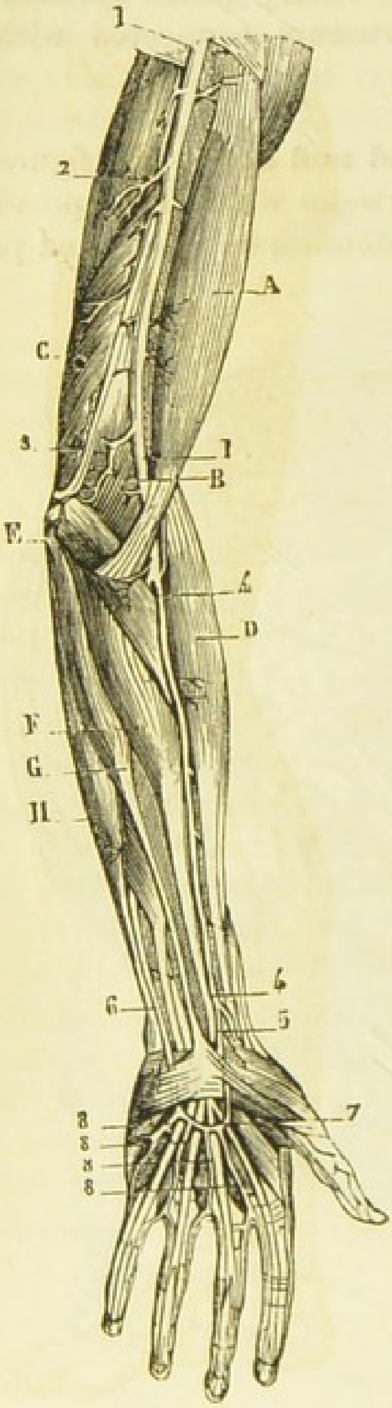


Fig. 330.*

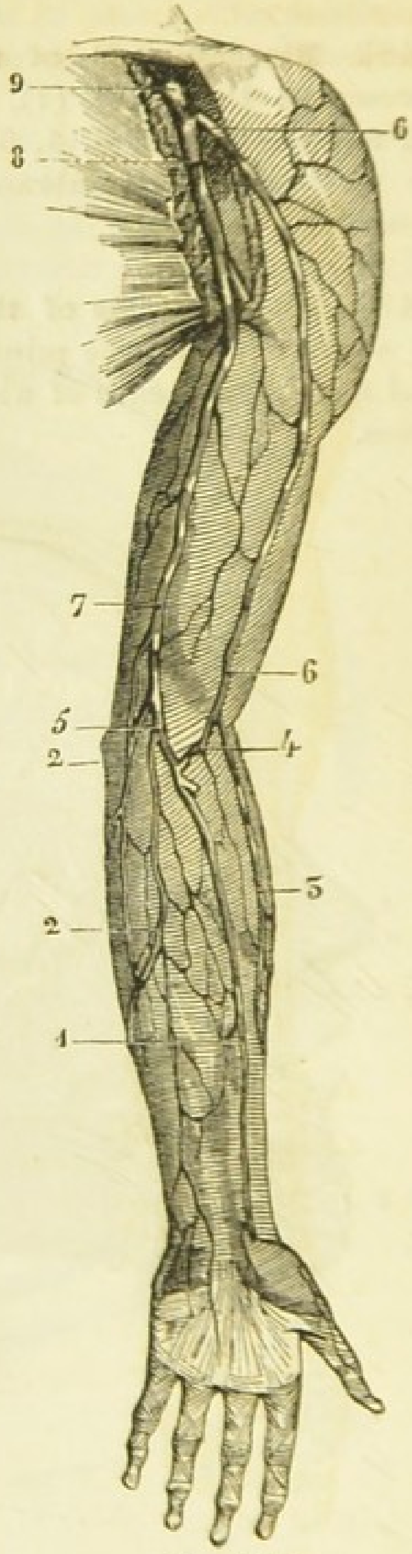


Fig. 331.*

which go to the teeth at 6; those which go to the mouth at 7; those of the palate at 8; those of the eye at 9, and so on.

* Sappey.

484. **Blood-vessels of the Arm and Hand.**—The principal arteries of the arm and hand are shown in fig. 330, and the superficial veins in fig. 331. In both figures the veins and arteries are indicated by numbers, and the muscles by letters.

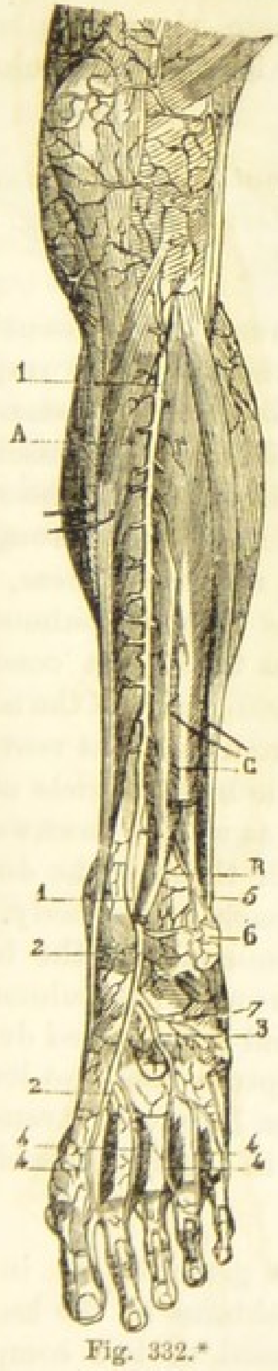


Fig. 332.*

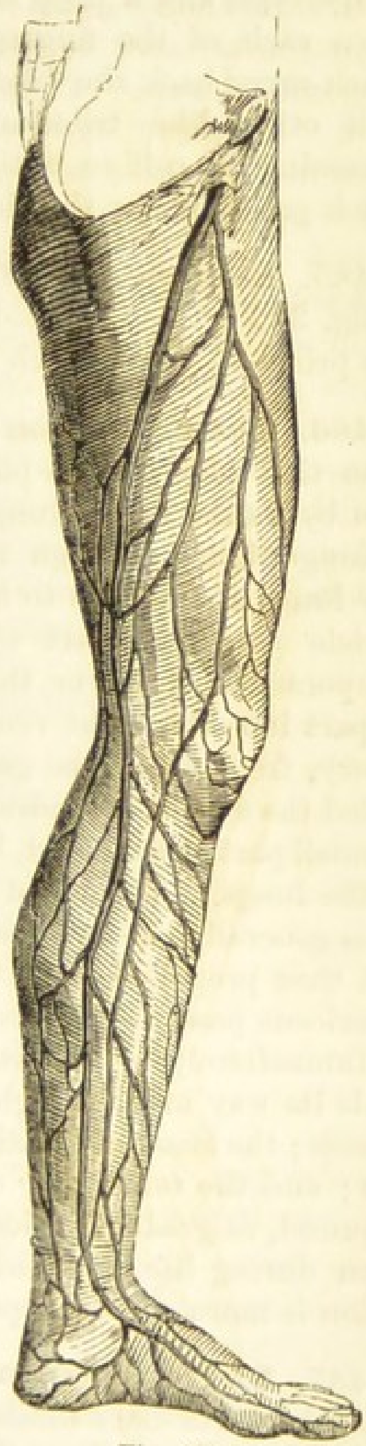


Fig. 333.*

In fig. 330, the artery, 1, called the humeral or brachial artery, passes down the arm, and within the hollow of the elbow is pro-

* Sappey.

tected by the tendon of the biceps muscle, A. Immediately below the elbow-joint it diverges into two, one of which, 4, 4, passes over the radius, and the other, 6, under the muscles, F, G, H; each then descends to the palm of the hand, and there forms a superficial and a deep arch, which sends branches, 8, 8, 8, 8, down each of the fingers. In fig. 331, the superficial veins which carry back the blood from the hand and arm, run into each other like tributaries feeding a large river, the veins increasing in calibre until they terminate in the great vein, 9, which passes under the shoulder.

485. **Blood-vessels of the Leg and Foot.**—In like manner in fig. 332 are represented the principal arteries, and in fig. 333 the principal veins which ramify over the leg and foot.

486. **The Circulation in the Fœtus** must differ essentially from that which takes place after birth, the process of respiration by means of the lungs being as yet dormant. Instead of passing wholly through the right ventricle and the vessels of the lungs and thence to the left auricle, the blood in the right auricle passes in part to the left auricle directly through a temporary opening in the septum which separates them, and in part into the right ventricle, and thence into the pulmonary artery, from which the greater part escapes through a conduit, called the ductus arteriosus, into the descending part of the aorta. A small part of the blood, however, passes from the right ventricle to the lungs. The blood propelled from the left ventricle circulates generally through the system upwards as well as downwards, but that propelled from the right ventricle through the ductus arteriosus passes exclusively to the lower parts of the body.

Immediately after birth, respiration commencing, the blood finds its way into the right ventricle and through the pulmonary vessels; the lesser circulation commences, and is continued during life; and the temporary opening in the septum being no longer required, is gradually closed. In rare cases, however, it remains open during life, in which case the blood in the systemic circulation is more or less impure.

487. **The Circulation in Mammifers** generally is in all essential particulars similar to that which obtains in the human economy. In all these the heart is composed of two compartments perfectly distinct, each of which has its own auricle and ventricle; and each of them, as in man, has the double circulation, the great and the lesser, the systemic and the pulmonary.

488. **The Blood of Birds** is more rich in red corpuscles than that of mammifers, and, instead of being circular, they are elliptical : their diameter is also greater. The circulation in birds differs in nothing essential from that of mammifers. The blood passes from the left ventricle of the heart into the arteries, by which it is distributed to all the organs ; and after passing through the capillaries, it returns by the veins to the right auricle, from which it passes to the right ventricle. It is thence propelled to the lungs through the pulmonary arteries, and returns by the pulmonary veins to the left auricle. The heart is similar in form, structure, and position, to that of mammifers. The aorta, after leaving the heart, is divided into three large trunks, two of which carry the blood to the head, wings, and chest ; and the third, being bent downwards round the right bronchial tube, is analogous to the descending aorta.

The venous system is terminated by three large trunks, one of which is the analogue of the venæ cavæ of mammifers, and the two others correspond nearly to the two innominate or brachio-cephalic veins, which however do not combine so as to form a single superior vena cava, as in mammifers.

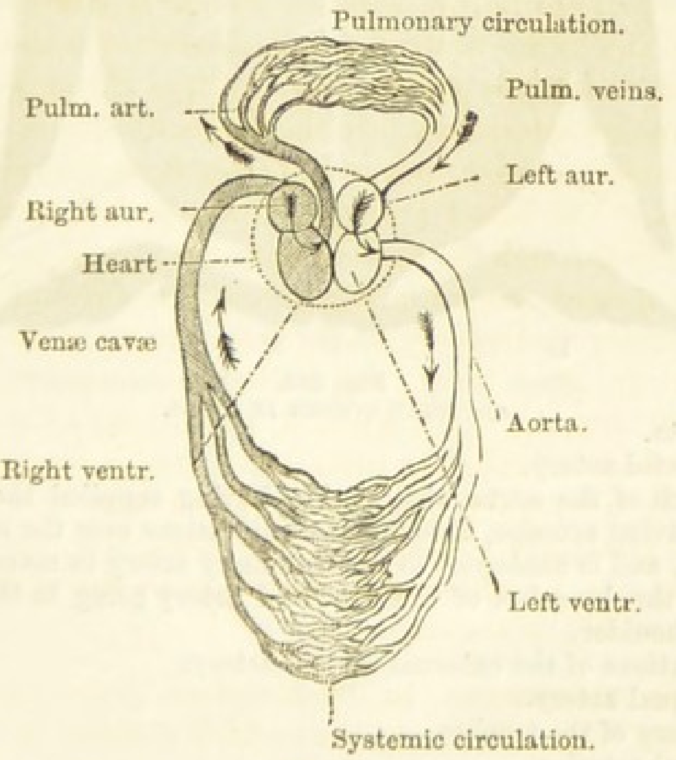


Fig. 334.

THEORY OF CIRCULATION IN MAMMIFERS AND BIRDS.

The general circulating system of birds will be better under-

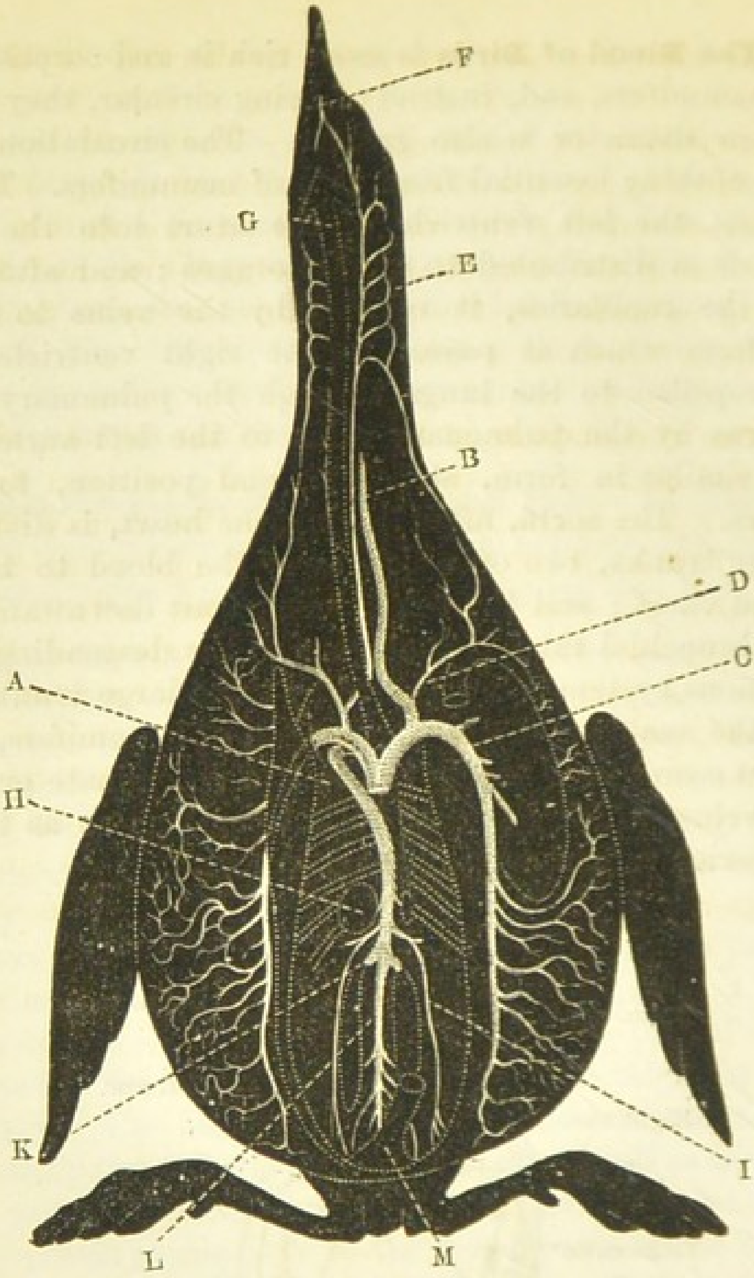


Fig. 335.
ARTERIAL SYSTEM IN BIRDS.

A. The aorta.
B. The carotid artery.
C. A branch of the aorta which, after having supplied the carotid and subclavian arteries, throws out ramifications over the muscles of the chest, and is analogous to the mammary artery in mammifers.
D. One of the branches of the vertebral artery going to the muscles of the shoulder.
E. Ramifications of the external carotid artery.
F. The lingual artery.
G. The artery of the trachea.
H. The renal arteries.
I. The femoral arteries.
K. The ischiatic artery, going to the inferior members.
L. The sacral artery, being a continuation of the aorta, and ramifying to form the inferior mesenteric artery and other small vessels.
M. The cloaca.

stood, after what has been explained, by the theoretical diagram, fig. 335.

The circulation in mammifers and birds will be rendered more intelligible by the theoretical diagram, fig. 334, where the vessels containing the venous blood are darkly shaded; those containing the arterial blood being white, and the capillaries being indicated by the dotted lines between the terminations of the arteries and veins.

489. **The Circulation of Reptiles** is incomplete, or rather, has a mixed character, being intermediate between the single circulation of mammalia before birth and the double circulation after it. The heart of reptiles has but one ventricle, which communicates at once with the pulmonary artery, the pulmonary vein, and the aorta or primary artery of the great circulation. A part only of the venous blood entering from the right auricle, passes into the pulmonary artery, and circulating through the lungs, returns through the pulmonary vein. This portion only, therefore, is reconstituted, and returning through the pulmonary vein, is again discharged into the single ventricle, whence, mixed with the other part of the venous blood

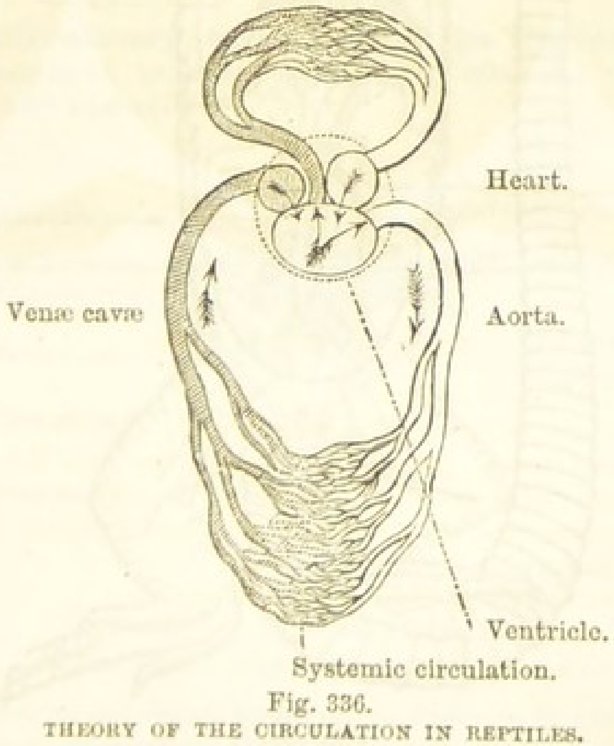


Fig. 336.
THEORY OF THE CIRCULATION IN REPTILES.

which does not circulate through the pulmonary vessels, it passes into the aorta and through the vessels of the great

circulation. These observations will be more clearly apprehended by reference to the diagram, fig. 336.

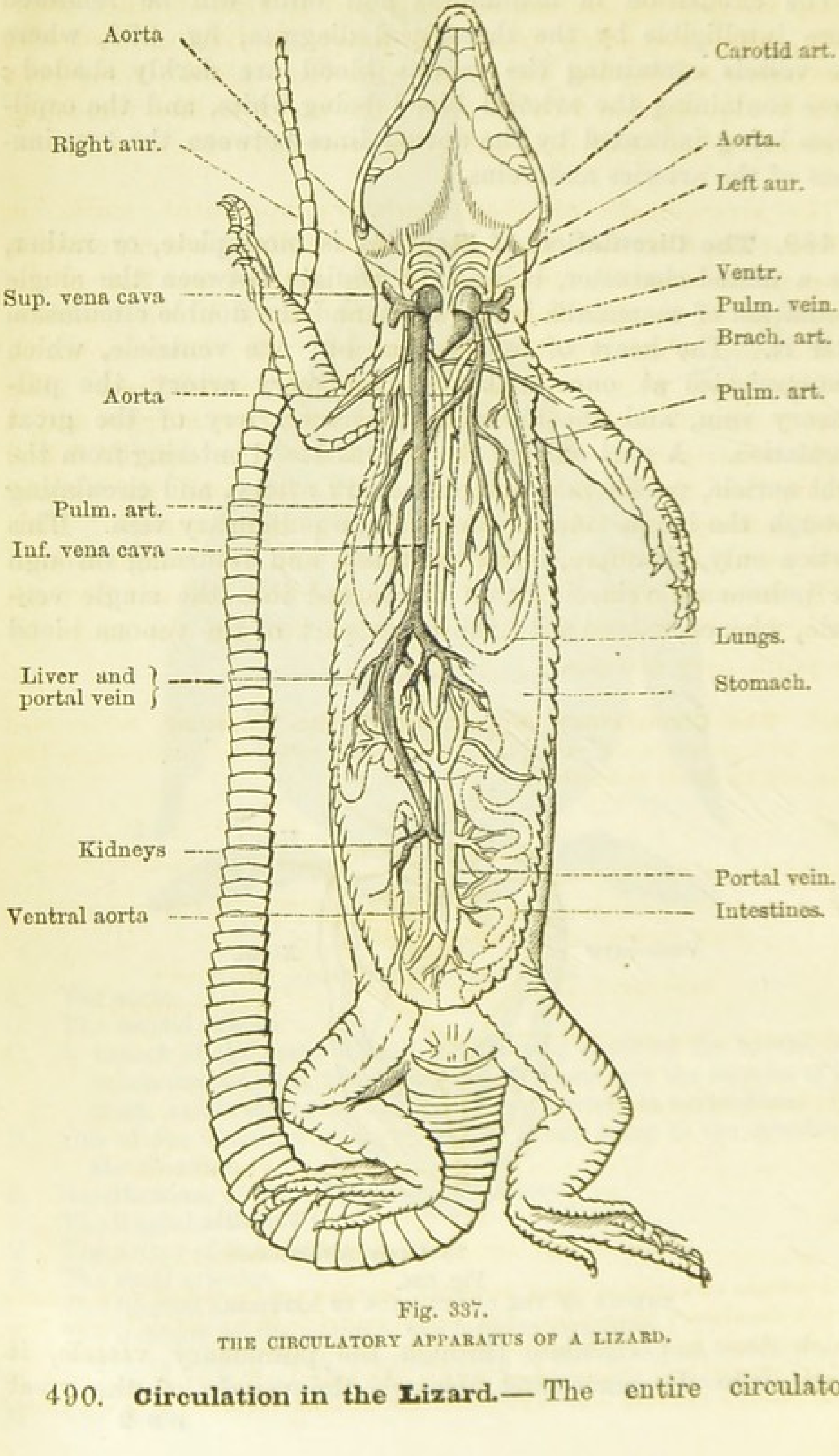


Fig. 337.

THE CIRCULATORY APPARATUS OF A LIZARD.

490. **Circulation in the Lizard.**— The entire circulatory

apparatus, as it exists in reptiles generally, is shown in fig. 337, which represents that of a lizard. It will be observed that the aorta, which in the human economy and in that of other mammalia, after ascending from the heart, is bent downwards, descending on the left side, is in this case double, being bent both to the right and to the left; the two branches reuniting, however, below the heart, and going vertically downwards.

The arrangement of the circulatory apparatus varies in different reptiles, but there is always a direct communication between the vascular apparatus of the arterial and that of the venous blood, so that these liquids are mixed in the ventricle of the heart which supplies the arteries. The consequence is, that the blood which circulates is imperfectly arterialised. The heart is almost invariably constructed with two auricles and a single ventricle, as shown in fig. 338. The arterial blood coming from the lungs is received in the left, and the venous blood coming from the capillaries in the right auricle. Both these auricles discharge their contents into the common ventricle, from which one part of the mixed blood is sent through the system by the aorta, and the other through the lungs by the pulmonary arteries.

491. **The Circulatory Apparatus of the Tortoise,** represented in fig. 338, presents an example of this, and after the explanation just given will be easily understood.

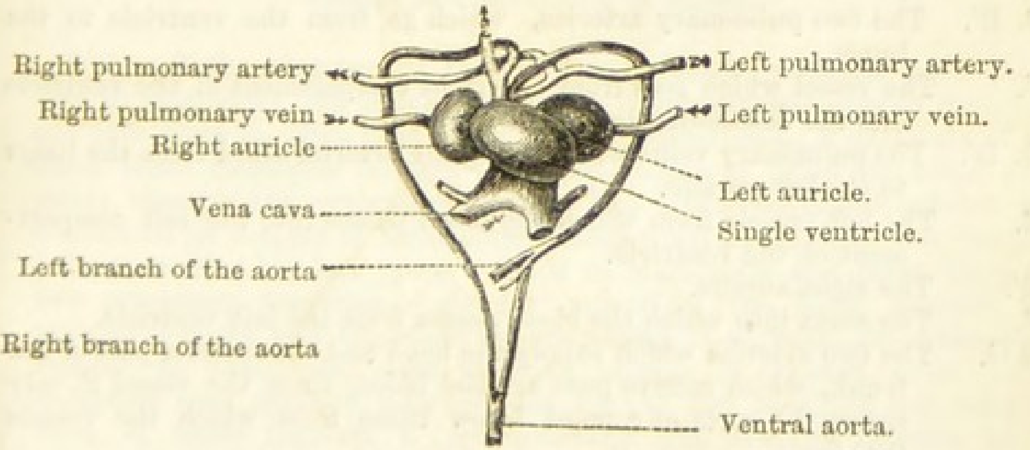


Fig. 338.
CIRCULATORY APPARATUS OF THE TORTOISE.

In certain exceptional cases, however, reptiles are furnished with a more perfect circulatory apparatus, the single ventricle being divided into two compartments by a membranous partition, which prevents the intermixture of the arterial and venous blood within the heart. Nevertheless, even in these cases, a mixture does take place, but at some distance from the heart,

in consequence of which one half of the body receives blood which is only imperfectly arterialised. In fact, the venous blood poured into the right compartment of the ventricle is not propelled exclusively to the lungs as in warm-blooded animals; for near the opening of the pulmonary arteries another vessel is found, which also proceeds from the right ventricle, and which, after being bent behind the heart, enters the descending branch of the aorta, and consequently mixes a portion of the venous with the arterial blood.

492. **The Crocodile,** whose circulatory apparatus is shown in fig. 339, presents an example of this.

Fig. 339.

CIRCULATORY APPARATUS OF THE CROCODILE.

V V. Veins which bring the blood from all parts of the body to the right auricle E′.

A. The ventricle divided into two compartments, right and left, by a partition.

B. B′. The two pulmonary arteries, which go from the ventricle to the lungs.

C. The vessel which goes from the right compartment of the ventricle into the descending branch of aorta.

D. D′. The pulmonary veins which bring the arterial blood from the lungs to the left auricle.

E. The left auricle from which the blood passes into the left compartment of the ventricle.

E′. The right auricle.

F. The aorta into which the blood passes from the left ventricle.

G G. The two arteries which supply the head and the anterior part of the trunk, which receive pure arterial blood, since the vessel F only enters the aorta at a point below those from which the vessels G G issue.

493. **Circulation in Fishes.**—The circulatory apparatus of fishes is still more simple, the heart having but one ventricle and one auricle. The blood is propelled from the ventricle through the gills, or respiratory apparatus (which will be more fully explained hereafter), where it acquires the nutritive

property, and from thence it passes directly, without returning to the heart, through the vessels of the great circulation ; and, after passing through the capillaries, it returns to the heart, enters the auricle, and passes from thence to the ventricle, and so on. This apparatus is represented by the theoretical diagram, fig. 340.

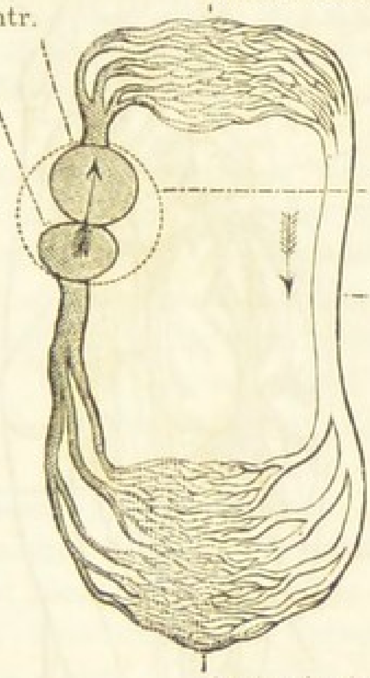


Fig. 340.

THEORY OF CIRCULATION IN FISHES.

Although the structure of the heart in fishes is so much more simple than in mammalia, the double circulation is nevertheless equally complete, and even more so, than in reptiles. In the latter class, a part only of the black blood circulates through the lungs, while in fishes the whole of it passes through the equivalent organ. The difference between fishes and mammalia in respect of circulation consists merely in this, that the propelling machine has less power ; while in mammalia and birds there are two propelling machines — one for propelling the blood through the systemic vessels, and the other for propelling it through the pulmonary vessels—in fishes, the same machine propels it through both. This difference may perhaps be explained by the fact that the less complex form of fishes requires a proportionally less powerful impulse to be given to the blood to enable it to return to the heart.

The arrangement of the circulatory apparatus will be understood by reference to fig. 341, where it will be seen that the heart is placed under the throat in a cavity separated from the abdomen by a sort of diaphragm, and surrounded and protected by the bones of the pharynx, the branchiæ, and the shoulder. It is composed of a single auricle, which receives the venous blood collected in a large receptacle near it, and of a single ventricle below, from which a branchial artery issues, the base of which

being enlarged, forms a contractile bulb. This vessel immediately diverges into two lateral branches, the ramifications of which are distributed through the branchiæ or gills, which, as will hereafter appear, are invested with the functions of the lungs. After traversing these organs, the blood remounts towards the head by another vessel, which is carried along the

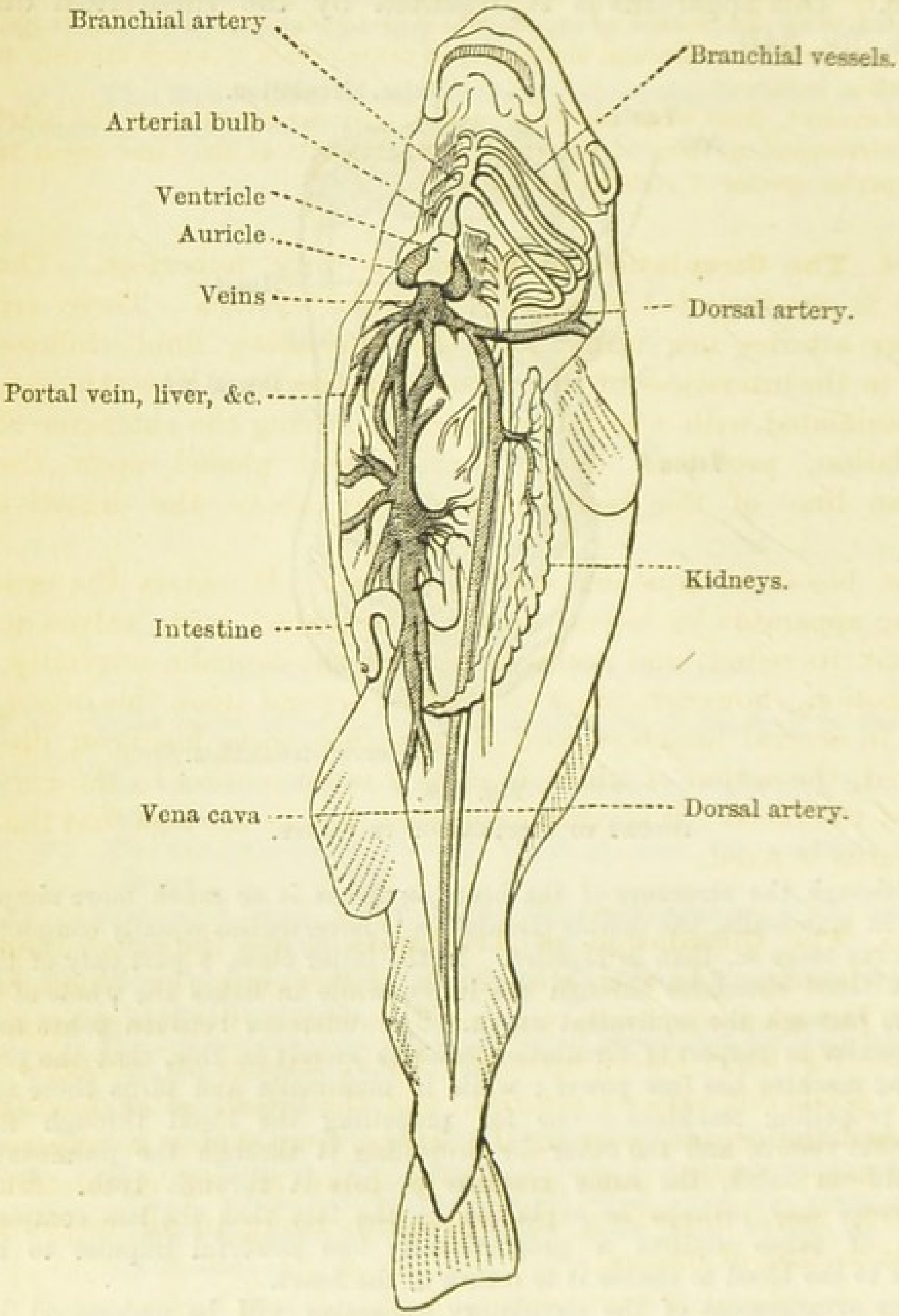


Fig. 341.
CIRCULATORY APPARATUS OF A FISH.

border of the branchial bones. After sending some branches to the neighbouring parts, these vessels reunite to form a great dorsal artery, which is directed backwards under the vertebral column, and throws out branches

to all parts of the body, as is shown in the figure. In returning to the heart, all the venous blood does not proceed directly to the receptacle leading to the auricle just mentioned; that which circulates in the intestines and some other parts being conducted into the liver before returning to the heart.

It appears, therefore, that as in mammifers and birds, the whole of the blood traverses the branchial organ, which is the equivalent of the lungs, but passes only once through the heart, in consequence of which its rate of circulation is slower.

It is evident, from what has been stated, that the functions of the heart itself correspond to those of the right compartments of the same organ in the superior species of vertebrated animals.

494. **The Circulation of Insects** is very imperfect. The blood is not included in a special vascular system. There are neither arteries nor veins, and the nourishing fluid diffuses itself in the interstices of the organs and tissues. Nevertheless, it is animated with a certain movement having the character of circulation, produced by a dorsal vessel placed upon the median line of the body, immediately above the digestive tube.

The blood is aqueous and colourless. It enters the propelling apparatus by lateral openings furnished with valves to prevent its reflux, and issues from it at the cephalic extremity. Its motion, however, does not solely depend upon this organ, since in several insects a sort of moveable valve has been discovered, the action of which imparts a rapid motion to the current of the blood: it is remarkable that it is in the legs that this apparatus is fixed.

495. **The Circulation of Arachnida** is less imperfect than that of insects. As with all animals of this class the blood is white, but some arachnida are provided with a circulatory apparatus. The heart placed upon the back, having an elongated shape, sends out various arteries, and the blood, after having traversed the organs, goes to the lungs, from which it returns to the heart. With other arachnida, however, the circulation is much more imperfect, the apparatus being in all respects similar to that of insects.

496. **The Circulatory Apparatus of Crustacea** consists of a heart with one ventricle, without an auricle, by which the blood is propelled through the arteries, capillaries, veins, and lungs, or substitutes for them. The veins, however, consist of irregular cavities, which do not take the usual vascular form,

and which constitute around the branchial canals a kind of venous reservoir. The venous blood, after thus bathing these organs, and recovering its nutritive properties, passes into tubes, which, corresponding with the pulmonary veins of superior animals, carry it to the heart. The arterial circulation is therefore systemic, and the venous respiratory.

In the case of crustacea, such as lobsters, crabs, crayfish, and other animals of the same class, the theory of the circulation, is represented in fig. 342.

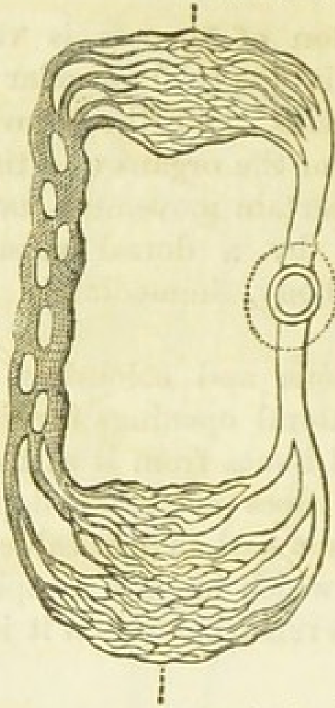


Fig. 342.

THEORY OF CIRCULATION IN CRUSTACEA.

497. The **Circulation in Mollusca** differs from that of fishes in nothing but the position assigned to the heart, which is placed in the current of black instead of red blood. In fact, if the heart be imagined in fig. 340 to be transferred from the middle of the veins where it is on the left of the figure to the middle of the dorsal artery on the right, the figure will then represent the theory of the circulation in mollusca. It will be observed, that in that case, the blood which passes through the heart will be red instead of being black as in fishes.

The actual circulatory apparatus will be more clearly comprehended by reference to fig. 343, in which the general

anatomy of a snail is represented, the parts being as follows :—

The heart of this class of animals is usually composed of a single ventricle *h*, from which the arteries *i* issue ; the auricles are sometimes double and sometimes single, and receive the red blood from the vessels *o o*, which may be regarded as pulmonary veins coming from the respiratory apparatus *d d*, to which the blood is conducted directly by canals more or less complete, having the venous character, such as *n n*. This is the case with snails, oysters, and all other mollusca of the gasteropodous and acephalous classes. There are, however, exceptional cases, in which no auricles are found.

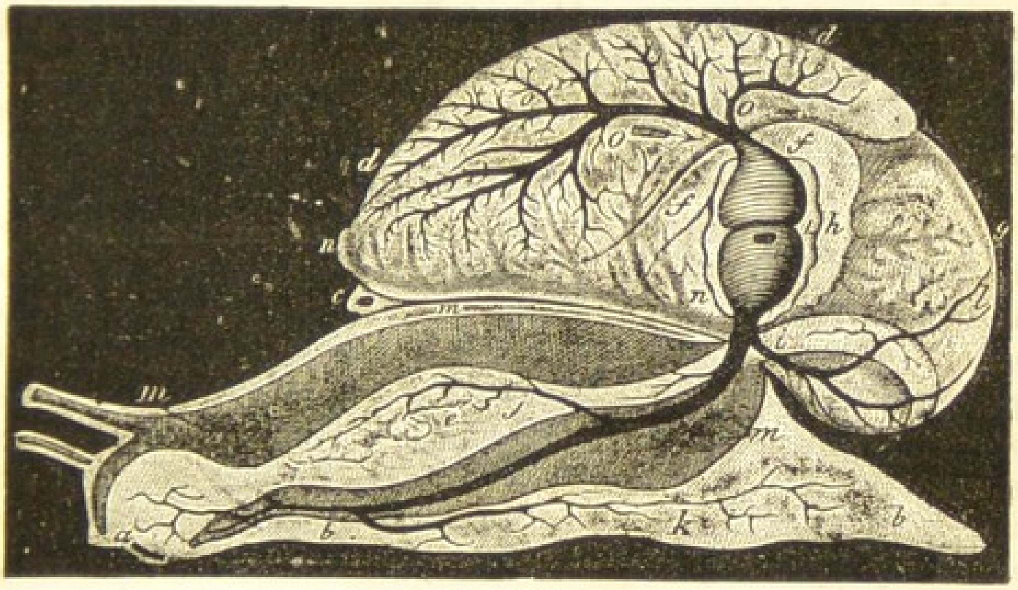


Fig. 343.

THE CIRCULATORY APPARATUS OF THE SNAIL.

a. The mouth.
b. The foot.
c. The anus.
d d. The lungs.
e. The stomach covered by the salivary glands.
f f. The intestine.
g. The liver.
h. The heart.
i. The aorta.
j. Gastric artery.
l. Hepatic artery.
k. Artery of the foot.
m m. The abdomen, having the function of a venous sinus.
n n. An irregular canal communicating with the abdomen and sending blood to the lungs.
o o. Vessels which carry arterial blood from the lungs to the heart.

498. **The Circulation of Zoophytes** is still more imperfect. In some of these, the holothuria and sea urchin, for example, a series of canals is discoverable, in which the blood circulates ; in others, such as the Medusa, the circulation is performed by appendages of the digestive tube. There are others in which the blood or nutritive fluid is diffused into the tissues by a sort of infiltration through the coats of the digestive tube, without any other discoverable mode of distribution.

CHAPTER VII.

THE LYMPHATICS.

499. **Absorption** is the name given to the process by which the organism receives from external sources the matter necessary to repair its waste and supply its growth. All matter taken into the system by this means must be in the fluid state, and food which is not naturally in that state must be reduced to it previously to its absorption by solution in the juices of the organs.

500. **Absorption may be exhibited experimentally** by various simple expedients. If a frog be immersed in water so as to prevent the water from entering its body except by the skin, it will be found after a certain time that a considerable quantity of water will have been imbibed by it, as will be proved by its increased weight. In like manner, a known volume of water being introduced into the stomach of a dog, all the passages from the stomach to other parts being previously closed by ligatures, the water will, after a certain interval, disappear, having passed through the membrane of the stomach to other parts of the system.

This process of absorption is ascribed to the physical agency already referred to (447), called endosmose and exosmose, and not to any such mechanical process as that by which water passes through the meshes of a sieve, or into the cellular interstices of a sponge.

501. **Lymphatics.**—Animals of the lower orders which have imperfect circulating apparatus derive their entire nourishment from this sort of cutaneous absorption ; but in classes supplied with a less imperfect circulatory mechanism, the function of nutrition consists, first, of absorption through the coats of the blood-vessels, and secondly, of the transfer of the nutritive matter by the current of the blood to the various parts of the organism. In the highest forms of organisation the process is still more complex. There the chief part of the absorption is performed by a vascular system specially appropriated to

that function, called the *lymphatics*, already mentioned (453).

502. **Thoracic Duct.**—The lymphatic vessels are systems of membranous tubes resembling the veins, but generally smaller, which pervade almost every part of the organism, following for the most part the same route. They generally run into each other like tributaries into a river, and then combining, form tubes of larger and larger calibre, until at length they form trunks of considerable diameter. The principal part of these vessels, converging from all parts of the body, finally coalesce, and discharge their contents into a large trunk, called the *thoracic duct* or *canal*, situated in front of and parallel to the spinal column. This canal discharges itself into a large vein situated near the heart, to the left of the base of the neck, called the subclavian vein of that side.

503. **Right Lymphatic Trunk.**—The lymphatic vessels of the right side of the body, including the arm, the chest, the neck and head, in like manner coalesce to form a canal, called the great right lymphatic trunk, which discharges its contents into the right subclavian vein.

The contents of the lymphatic system being thus discharged into the two subclavian veins, are finally conducted, mingled with the venous blood, into the right auricle of the heart.

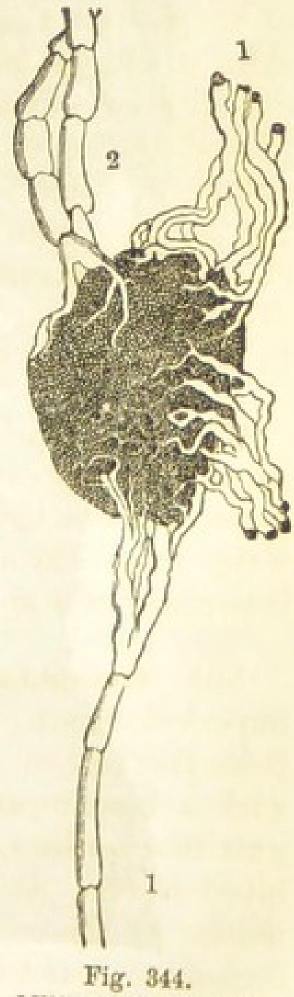


Fig. 344.
LYMPHATIC GLAND.

504. **Lymphatic Glands.** — A circumstance of considerable importance is observed in the structure of the lymphatics, which requires special notice. In their course through the body to their points of junction with the venous system they are interrupted in various places by vascular masses of greater or lesser magnitude, into which they seem to discharge their contents. From opposite sides of these masses other vessels, generally of greater calibre, issue, which continue their course. Between the origin of the lymphatic system and its points of junction with the venous, its course is thus

frequently interrupted ; and in all cases where its continuance is resumed, the vessels acquire increased magnitude.

Lymphatic Glands is the name given to these vascular masses, and the manner in which the lymphatics enter and leave them is illustrated in fig. 344, where 1 1 1 are the lymphatics entering, and 2 2 those issuing from them. These glands are generally of irregular roundish forms, and are found in various parts of the body, but more especially in the armpits, groins, neck, chest, and abdomen.

505. The thoracic duct, and the lymphatics and glands immediately connected with it, are shown in fig. 345, the parts being as follow :—

1. The thoracic duct passing in front of the vertebral column by the side of the azygos vein.

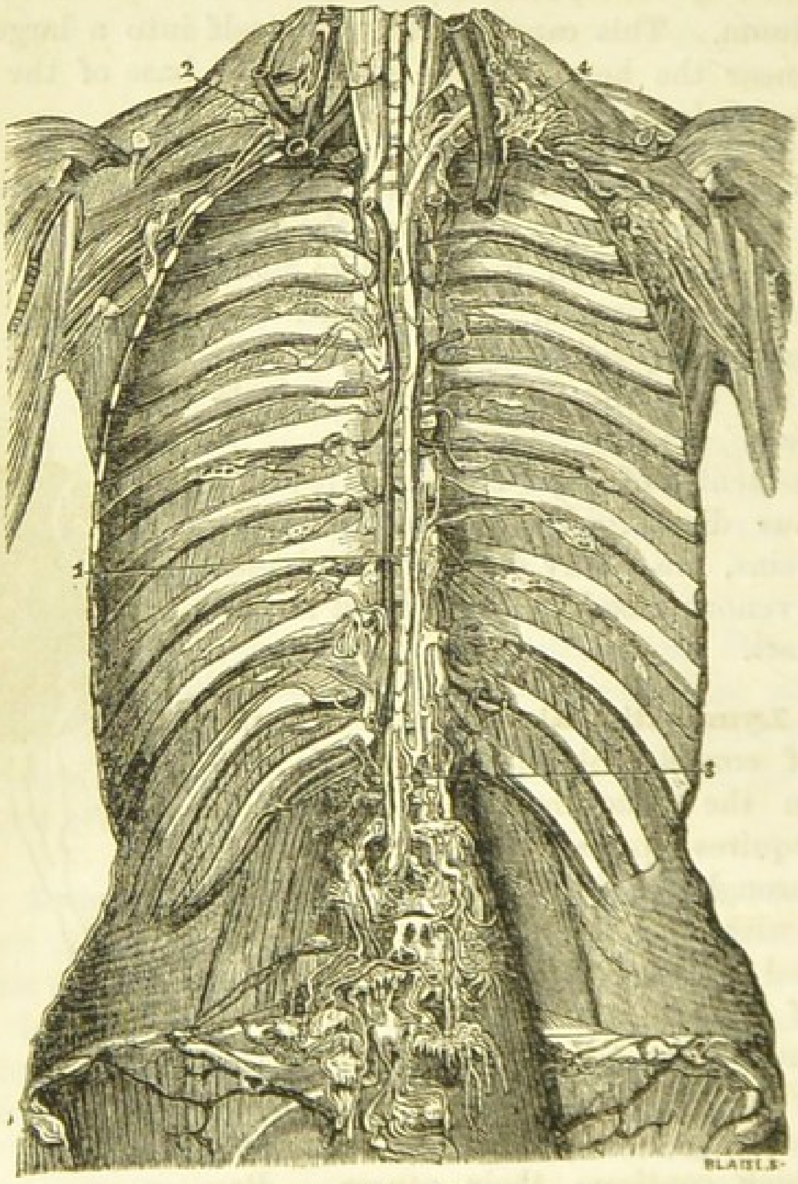


Fig. 345.
THORACIC DUCT AND GREAT LYMPHATIC TRUNK. (Mascagni.)*

* Vasorum lymph. Hist. P. Mascagni. Senis, 1787.

3. The origin of the thoracic duct at its confluence with the lymphatic vessels. These vessels are seen proceeding from the lymphatic glands of the abdomen, many of which appear at the lower part of the figure.

4. The point of confluence of the thoracic duct and left subclavian vein near the junction of the latter with the left jugular vein.

2. The large lymphatic vessels proceeding from the right side of the head, and discharging their contents into the right subclavian and jugular veins.

506. It is impossible to contemplate the structure and disposition of the lymphatics as here described without being struck with their analogy to the system by which a country is drained. The vessels in their most minute state of subdivision being scarcely more than microscopic, are distributed upon organs which are saturated with the fluid which it is their function to absorb. This fluid passes into them as the water which saturates a boggy soil passes into drains cut in various directions through it. These drains converging into a common channel, form a large stream; this stream, after pursuing its course for a distance more or less considerable, spreads out into a pool, where it absorbs fresh supplies. This is just what happens in the lymphatic system in passing from gland to gland. From this pool or lake a larger stream issues, which, converging with other streams, forms a considerable river; and thus tributary after tributary converging and coalescing, a vast river pours its waters into the sea; just as the thoracic duct and great lymphatic trunk pour the floods of nutrition which have been collected and absorbed through the system into the subclavian veins. The fluid mixture is conducted to the right auricle of the heart, whence, as described in the last chapter, it is conveyed through the right pulmonary arteries to the lungs, where it is exposed to the action of the oxygen of the atmosphere by a process which will be described in the next chapter. This last process is all that remains to reconvert the spoiled and used blood into fresh and nutritious arterial blood.

507. **Contractile Action of the Lymphatics.**—In the case of a river and its tributaries, to which we have compared the lymphatic system, the force which carries the fluid to the sea is gravitation acting along the descending beds of the several streams, and that of the principal river. In the animal economy, however, gravity, so far from aiding the march of the fluid through the vascular system, in most cases opposes it, the currents being directed upwards.

In the case of the arteries, we have seen that the moving

force is the contractile action of the muscles of the heart, combined with the elastic power of the coats of the arteries, to which the valves of the heart supply points of reaction.

It may then be asked, whether there is in the lymphatic system any propelling power, analogous to that of the heart. It is certain, that in mammifers, at least, there is no such organ, nor any which is analogous to it; and, consequently, the current of the fluid can only be maintained by the contractile action of the lymphatics.

508. **The Internal Structure of the Lymphatics** indicates, if it do not fully prove, the existence of this contractile force. Like the veins, they are supplied with a series of semilunar valves, which prevent the reflux of the fluid, and supply points of reaction. One of the vessels laid open, so as to display the form and arrangement of these valves, is shown in fig. 346.

Fig. 346.
SECTION OF A LYMPHATIC VESSEL SHOWING THE VALVES.

509. The membrane of the lymphatics is nearly transparent, and the lymph (453), with which most of them are filled, when not mixed with products of digestion, is also transparent and slightly yellowish in colour. When submitted to the microscope, colourless spherules are seen floating in it, which are smaller than the red corpuscles of the blood, and are, in fact, identical with the white corpuscles (445) seen floating in the blood.

510. **Chyliferous Vessels.**—The lymphatic vessels, which prevail in the region of the intestines, receive the chyle (453), by absorption, but do not differ in other respects from the lymphatic system. The lymphatics which thus conduct the chyle are sometimes denominated *Chyliferous or lacteal vessels.*

511. **Absorption by the Lymphatics** is demonstrated by various easy and simple means. If the abdomen of an animal whose digestion is in full action be opened, the lymphatic vessels of the intestines will be observed to be gorged with chyle, proceeding from the digested food. But, if the same vessels be examined in an animal after a long fast, they will be found empty and colourless.

512. **The Movement of the Lymph and Chyle** through the lymphatics is favoured by various anatomical and physiological conditions.

It is easy to show that the transverse section of the thoracic duct, of the great lymphatic trunk, and of the vessels which immediately lead to them, is less than the sum of the transverse sections of all the lymphatic vessels which flow into them. The necessary consequence is, that in proportion as the passage open to the fluid is diminished, the velocity of the current is increased. This fact, however, though represented by some physiologists as an active accelerating principle, cannot be so understood; for, though the velocity of the fluid in the narrower passages is greater, the quantity which passes in a given time, and the propelling force, are absolutely the same.

513. The muscular action attending locomotion accelerates the progression of the lymph in the lymphatic vessels of the members. The contraction of the abdominal muscles produces the same effect on the progression of the chyle in the vessels of that region.

514. The mechanical phenomena of respiration, which will be more fully described hereafter, act in two ways, to favour the current of chyle and lymph towards the thoracic duct. The tendency to a vacuum, produced by the expansion of the thorax during each inspiration, not only causes the afflux of atmospheric air into the lungs, but also that of all the liquids which have access to the chest. Thus the liquid contained in the abdominal part of the thoracic duct, and in the nearest lymphatic vessels, is attracted towards its thoracic part during each inspiration. On the other hand, expiration, accompanied by the contraction of the abdomen, has a like effect, since it tends to make the liquid of the thoracic duct pass with more force from the abdominal to the pectoral region.

515. **Structure of the Lymphatic Glands.**—It was formerly supposed that in passing through the glands, the lymphatics entered into direct communication with the blood-vessels. The researches of modern physiologists have proved this to be an error. A lymphatic gland, as shown in fig. 344, consists of a mass of minute lymphatic vessels, among which numerous sanguiferous capillaries ramify. Between the two sets of vessels there is no inosculation. They conduct their respective fluids altogether independently of each other. The lymph which passes into the gland by the afferent vessels, passes out of it by the efferent ones, having in the gland been infinitely subdivided by the minute and multiplied tubes which form the

substance of the gland. Whether there is any interchange between the blood of the capillaries in the gland by exudation or exosmose and the lymph of the smaller lymphatic vessels, is mere matter of conjecture, unsupported as yet by any results of immediate observation.

516. **Sources of Lymph.**—The liquid part of the blood, called the *liquor sanguinis*, or *plasma*, charged with nutritive principles, exudes by the process of exosmose through the coats of the capillaries, and being diffused among the tissues, supplies to them respectively the matters proper for their

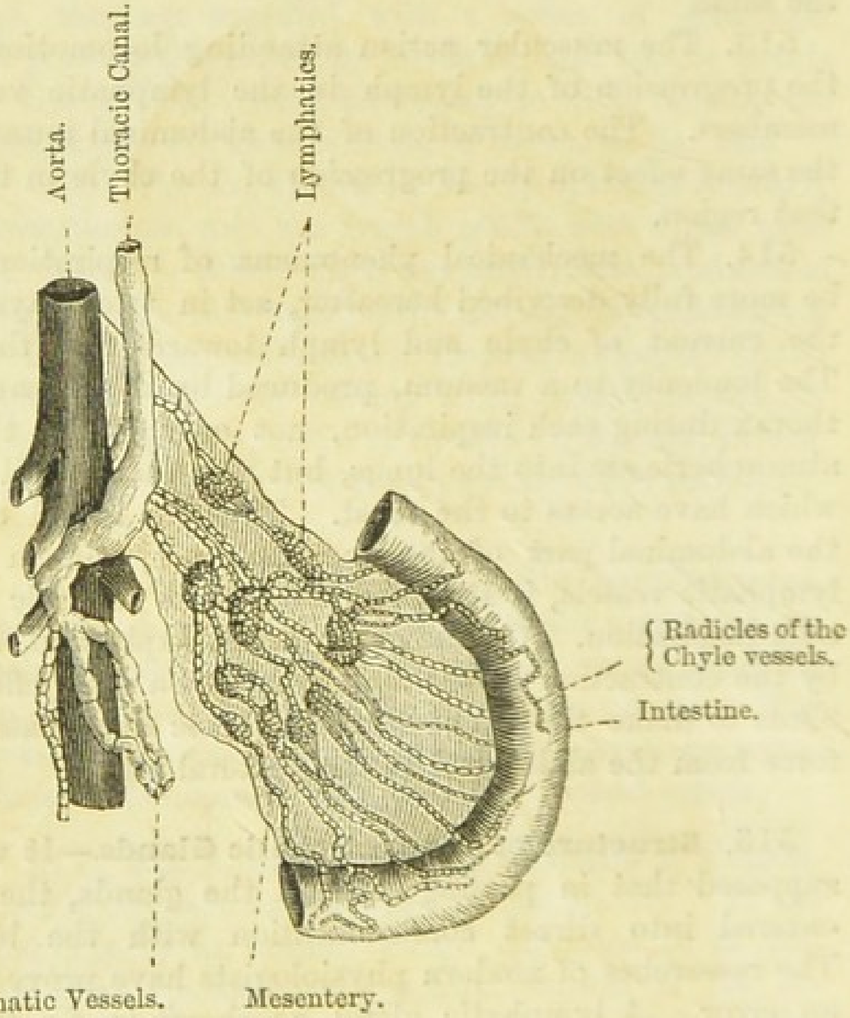


Fig. 347.
CHYLE VESSELS OF THE MESENTERY.

repair. The residuum of the plasma is absorbed by the multitude of lymphatics which pass through the same parts, into which it enters by the process of endosmose. In this state it constitutes lymph, and is carried back by the lymphatic vessels to the subclavian veins.

It is probable that some interchange takes place in this case between the lymphatic vessels and the surrounding matter; and that, while they receive the residuum of the plasma, they may give out to the tissues by exosmose some of their constituents. These are points, however, upon which much uncertainty still rests.

It is certain, however, that the lymph is rendered coagulable by the fibrine which it receives from the plasma, more especially in passing through the glands.

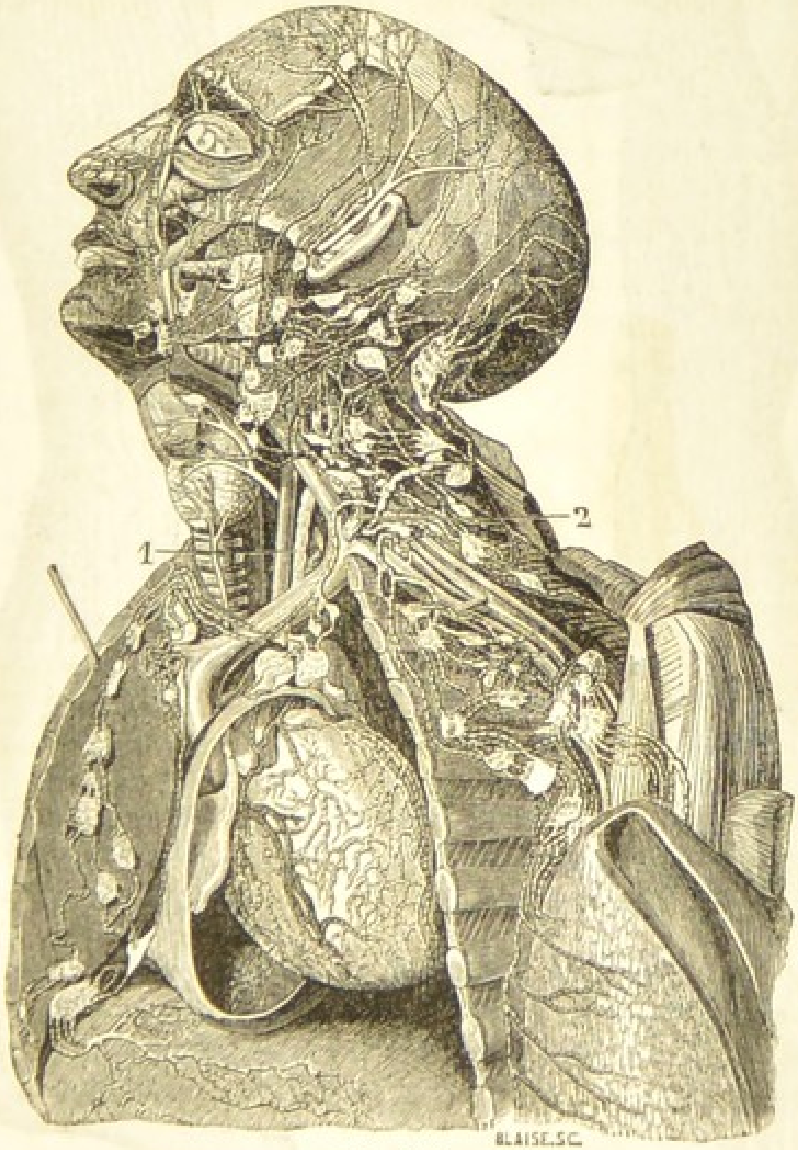


Fig. 348.

LYMPHATICS OF THE UPPER PART OF THE TRUNK AND HEAD (Mascagni).

517. **Beautiful Structure of the Lymphatics.**—There is no part of the organisation the structure of which presents a spectacle more curious and beautiful than the lymphatics. We

shall, therefore, give here some examples of their structure. In fig. 347 are shown the chyliferous vessels of the *mesentery*. These are spread over the intestines on the one side, whence

Fig. 349.
LYMPHATICS OF THE ARM AND HAND (Mascagni).

Fig. 350.
LYMPHATICS OF THE LEG AND FOOT (Mascagni).

they absorb the chyle, and, passing over the mesentery, are

transmitted through a multitude of glands from which larger vessels issue, which eventually terminate in the thoracic duct.

In fig. 348 are represented the lymphatics of the diaphragm, the heart, the breast, the armpit, the head, and the neck.

In fig. 349 are shown the lymphatics of the arm and hand, and in fig. 350 those of the leg and foot.

In figs. 319, 320, are shown the lymphatics of the heart.

518. **The Lymphatics of all Vertebrate Animals** of the inferior classes are similar to those of man. In the case of certain reptiles—the frog, for example—their structure is often more complicated than in warm-blooded animals. In the course of the lymphatic vessels of these are found certain enlargements, provided with muscular fibres, which have been called *lymphatic hearts*, whose contraction produces the same effect in propelling the lymph as the heart produces upon the circulation of the blood. In both reptiles and fishes the lymphatic vessels are relatively more voluminous than in mammifers or birds. Lymphatic glands, however, are generally absent in these classes. The valves are less numerous, and in some cases altogether absent.

519. In the larger class of Mammifers, the lymphatic and chyliferous vessels converge in a single thoracic duct, as in man. Frequently, however, this canal consists of two ducts, which remain separate up to the point where they enter the left subclavian vein. In other cases, although the thoracic duct is double in its pectoral part, and as far as the commencement of the cervical part, the two branches unite at the moment of joining the venous system.

520. **The Lymphatic Vessels of Birds** form by their union two thoracic ducts, which appear on each side of the base of the neck, uniting with the jugular veins.

521. **The Lymphatics of Reptiles and Fishes** terminate in the venous system by communications more or less numerous. The most frequent and largest of these communications are made with the veins in the immediate neighbourhood of the head.

In mammifers generally, the lymphatic glands are numerous, and it is probable that they have no direct communication with the venous system.

522. **The Invertebrate Classes** have neither chyliferous nor

lymphatic vessels. There is no proper distinction between the blood and the product of digestion, or it may rather be said that this product constitutes the blood itself. In those which have a complete circulating apparatus with arteries distinct from the veins—such, for example, as the mollusca—it is probable that the veins which circulate over the intestines absorb the products of digestion, and transfer them to the region of the respiratory organs. In arachnida, crustacea, and annelida, whose apparatus of circulation is less complete, the product of digestion passes through the coats of the intestines, and is diffused through the regions which surround the digestive canal, and from thence, by imbibition and endosmose, is transmitted to the circulatory vessels.

523. **In Insects** the liquid product of digestion, after it has passed the coats of the digestive tube, does not pass into any circulating vessels properly so called ; it is merely diffused through the cellular interstices which exist among the organs, and thence into the organs themselves.

524. **Radiata**, excepting the echini and holothuria, have no vascular system, and the products of digestion pass through the sides of the digestive cavities directly into the tissues. The acalephæ, which belong to this class, and which have the form of fungi, present a remarkable arrangement. The digestive cavity in these presents a multitude of parts, forming a complicated net-work, and the products of digestion escape through the sides of these minute reticulated intestinal tubes, their dispersion through the system being thus facilitated.

CHAPTER VIII.

RESPIRATION.

525. **Respiration** is the function by which venous is reconverted into arterial blood.

526. The seat of this process is the lungs.

527. The change produced by it in the blood consists in imparting to it a portion of the oxygen of the atmospheric air which enters the lungs, and in extricating from it a nearly equal volume of carbonic acid. This interchange takes place through the membrane in which the pulmonary capillaries run, by the process *exosmose* and *endosmose.** After this interchange the blood loses its venous character and becomes arterial. From a blackish-red colour it acquires a bright vermilion, regaining at the same time its nourishing property. In this state it returns to the left vessels of the heart, from whence it again passes into the circulation.

528. **Inspiration and Expiration.**—The air in the lungs being thus deprived of its due proportion of oxygen, and being charged with carbonic acid, is no longer capable of arterialising the blood ; it must therefore be expelled from the lungs and replaced by pure air. This is accomplished by the alternate contraction and expansion of the thorax. By its contraction the air is forced out through the windpipe and air-passages of the mouth and nose, and by its subsequent expansion fresh air is drawn in through the same passages. The contraction produces expiration, and the expansion inspiration. The play of this thoracic mechanism, and the consequent alternation of inspiration and expiration, never cease so long as life continues. The first act of the infant on entering the world is inspiration, and the last of the dying on leaving it expiration. So imperious is the necessity for the continuance of this process that its temporary suspension is attended with danger, and, if prolonged beyond a certain limit, with death.

529. Respiration involves therefore two classes of phenomena, the one mechanical and physical, and the other chemical and physiological, which must be separately explained.

* Hand-book of Nat. Phil. Hydrostatics, § 113.

530. **Mechanism of Respiration.**—The mechanism by which the alternate enlargement and contraction of the capacity of the thorax are produced consists in the peculiar structure of that bony cage, the muscles which act upon its moveable parts, and the motor nerves by which these muscles are excited.

The thorax, as already explained (95), is a conoidal cage of a bee-hive form, the framework of which consists of the spinal column behind, the sternum or breastbone before, and the ribs at the sides. Relatively to the other parts the vertebral column is fixed ; the ribs are moveable, within certain limits, on their articulations with the vertebræ. They are moveable also relatively to the sternum, by reason of the flexibility of the cartilages by which they are connected with it.

In the state of repose which follows an expiration, the capacity of the chest being reduced to its least limit, each pair of ribs is inclined downwards and forwards, and the sternum is depressed. To enlarge the chest during an inspiration each pair is drawn up to the horizontal position, and, at the same time, the sternum is elevated and protruded forwards. This movement produces an enlargement of the thorax by two of its dimensions ; firstly, by its increased depth from the sternum to the vertebral column, and secondly by its increased width from side to side.

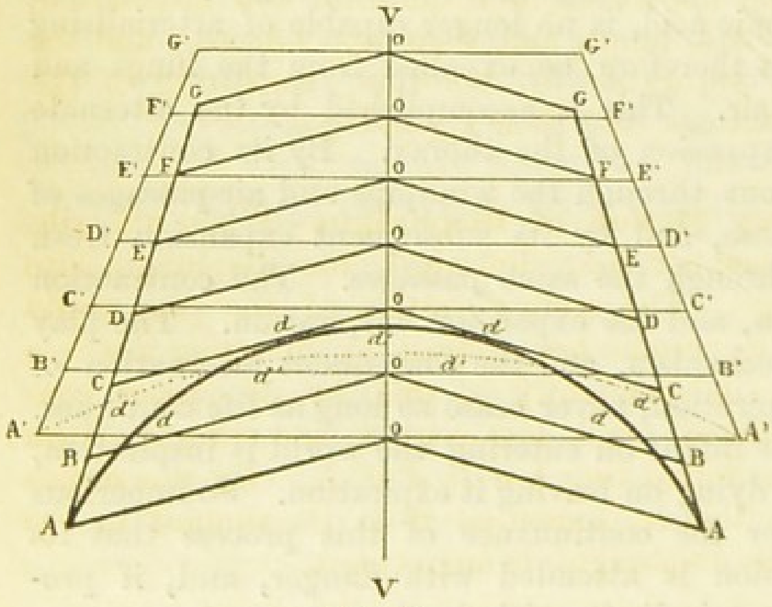


Fig. 351.

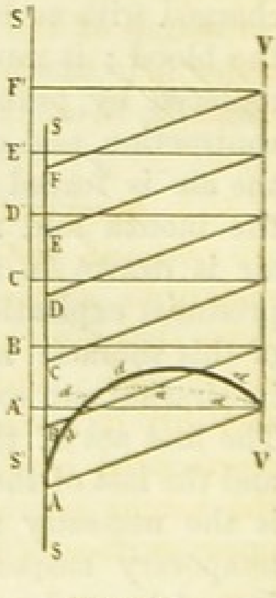


Fig. 352.

531. **Motion of Ribs and Sternum.**—That such an enlargement of capacity must ensue will be rendered apparent by the geometrical figures 351 and 352 ; the former being supposed to present a front, and the latter a side view of the chest.

The ribs, when in a state of repose and inclined downwards from the vertebral column, V V, are represented in fig. 351 by o A, o B, o C, o D, o E, o F, and o G. In fig. 352 the line S S is supposed to represent the sternum. The position of the ribs, when raised as already described, is shown by A′, B′, C′, D′, E′, F′. In fig. 352 it will be seen that by this elevation of the ribs the sternum, S′ S′, is at the same time raised and thrown forward. It will be evident by a mere inspection of these figures that by this movement of the ribs upon their articulations, *o*, the transverse diameter of the thorax is augmented, A′ A′, B′ B′, &c. being obviously greater than A A, B B, &c. Thus the two dimensions of the thorax, one directed from the front to the back, and the other from side to side, are both increased.

532. **Base of the Thoracic Cavity, the Diaphragm.**— The spaces between the ribs are closed by the intercostal muscles. The base of the thorax is closed by the diaphragm, a muscle having nearly a hemispherical form, convex upwards and concave downwards, which is inserted in front in the sternum, behind in the vertebræ, and all round the sides in the ribs. This muscle is represented in the figures by the curved line A *d d d d* A, which divides the trunk into two compartments, the upper or pectoral included by the ribs, sternum, and vertebral column; and the lower, or abdominal, included by the muscles and integuments of the abdomen and the lower part of the vertebral column. The pectoral compartment is appropriated to the apparatus of respiration and circulation, consisting of the heart, lungs, and their appendages; and the abdominal to the apparatus of digestion, consisting of the stomach, liver, intestines, and their appendages.

533. **Respiratory Motion of Diaphragm.**—When the ribs are raised in the manner here described, the diaphragm also undergoes a change. The mere elevation of the ribs would cause that muscle to become less convex by enlarging the area of its base; but, independently of this, by its proper contractility it is rendered much less convex, assuming the form represented by the dotted line A *d′ d′ d′ d′* A. By this means the height of the thorax, measured from its summit to the upper surface of the diaphragm, is augmented.

How great an increased capacity can thus be given to the thorax by a comparatively small increase in each of its dimensions may be easily shown. Let us suppose, for example, that its depth, width, and height are each increased in the proportion of 4 to 5; in that case its capacity would be increased in the proportion of

$$4 \times 4 \times 4 \text{ to } 5 \times 5 \times 5,$$

that is, in the proportion of 64 to 125, or 2 to 1 very nearly. Thus an increase which would augment each of the dimensions in a proportion not greater than one-fourth would double its capacity.

534. **Respiration illustrated by a Bellows.**—This alternate enlargement and diminution of the thorax by the elevation and depression of the ribs and diaphragm in respiration, are

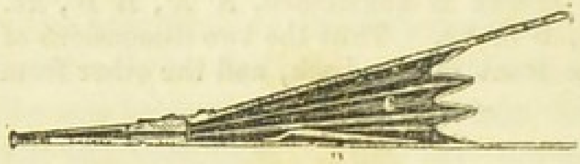


Fig. 353.

in all respects similar to the action of the common bellows (fig. 353).

The ribs may be considered as analogous to the two boards A and B which open and close, their articulation with the spinal column to the hinges on which these boards play, and the diaphragm to the flexible leather by which the boards are united—the nozzle, E, being the representative of the trachea or windpipe. When the ribs are elevated and the diaphragm extended and rendered less convex, the thorax represents the bellows with its boards separated. The enlargement of the capacity of the interior causes the external air to rush in through the windpipe to fill the vacuum which would thus be created.

When the ribs are, on the contrary, depressed, and the diaphragm recovers its convexity, the internal cavity, being forcibly diminished, expels the air through the windpipe in the same manner exactly and upon the same mechanical principle as the air included in a bellows is expelled through the nozzle by forcing together its boards.*

535. **Intercostal Muscles.**—To render this operation effective, it is obvious that the thorax, like the bellows, must be air-tight. It is rendered so by the intercostal muscles and the diaphragm, which close all the passages both on the sides and at the base. The intercostal muscles consist of two layers superposed one upon the other, denominated the external and the internal. The fibres of each of these are arranged in a direction parallel to each other, and oblique to the ribs,—those of the external being nearly at right angles to those of the internal.

536. **The Thorax with its Appendages** is shown in fig. 354, the intercostals being removed from one side in order to display the form of the diaphragm, the position of the parts

* Hand-book of Hydrostatics and Pneumatics, 256.

being that which they have in a state of repose, when the ribs are depressed after an expiration. It will be seen that the diaphragm ascends into the interior of the thorax to nearly half its height, and that its outline is not regularly convex, being somewhat depressed at the summit.

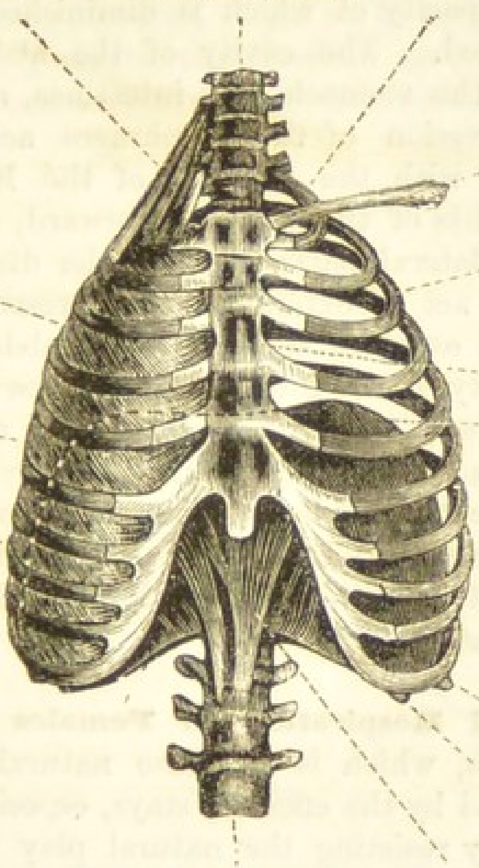


Fig. 354.

THE THORAX WITH ITS PRINCIPAL MUSCULAR APPENDAGES.

The external intercostals are shown on the left side of the figure, where the fibres are inclined obliquely from each rib downwards and forwards to the next below it. The internal intercostals are concealed by the external, but the position of their fibres may be easily understood by considering that they are at right angles to those of the external intercostals, and are consequently inclined obliquely backwards from each rib to the rib below it.

Some of the elevator muscles of the ribs are shown in the upper part of the figure, having their origin in the cervical vertebræ, and their insertion in the upper ribs. The cartilages of the ribs are distinguished from the bony part by their light colour.

The diaphragm is connected at its inferior surface with the lumbar vertebræ by muscles called its *pillars* or *crura*, and the ribs are severally connected with the vertebræ placed above them by several smaller levator muscles.

537. **Action of the Diaphragm in gentle Respiration.**—The respiratory action in man, when the body is not excited by exercise or labour, is performed by the elevation and depression of the diaphragm, accompanied by a motion of the lower ribs. The enlargement of the thorax produced by the depression of the diaphragm is effected at the expense of the abdomen, the capacity of which is diminished as that of the thorax is enlarged. The cavity of the abdomen, however, being filled by the stomach, the intestines, and their appendages, the depression of the diaphragm acting upon these parts, combined with the reaction of the lumbar vertebræ, presses the contents of the abdomen forward, so as to protrude its anterior and lateral parts. When the diaphragm is again elevated by the act of expiration, the pressure of the atmosphere upon the external surface of the abdomen, combined with the elasticity of the integuments, forces the stomach and intestines backwards and upwards, so as again to fill the enlarged space under the diaphragm.

538. Such are the physical causes which produce the alternate heaving inwards and outwards,—or rather, the alternate swelling and contraction—of the abdomen which accompanies the act of respiration.

539. **Pectoral Respiration in Females** is greater than abdominal. This, which is the case naturally, is, however, greatly augmented by the effect of stays, especially when tightly laced. These, by resisting the natural play of the abdomen, obstruct the action of the diaphragm, and render necessary an augmented play of the pectoral mechanism. This exaggerated pectoral respiration is visible in the habitual heaving of the female bosom.

540. The intercostal muscles, having their origin in one pair of ribs and their insertion in the other, cannot act directly either as levators or depressors, from the want of fixed points of reaction : but when the ribs are rendered relatively fixed by the action of other muscles, then the contractile power of the intercostals comes into play. In fact the intercostals, properly speaking, ought to be regarded as the mere continuations of other muscles, never acting except in co-operation with them.

541. **Respiratory Action of the Intercostals.**—Much difference of opinion has prevailed among physiologists as to the

functions of the intercostals ; some considering the external as elevators, and the internal as depressors ; others, on the contrary, regarding the external as depressors, and the internal as elevators; while others again have ascribed the same functions to both ; and, in fine, some insist that these muscles have no influence whatever on the movement of the ribs. The question, however, seems to be satisfactorily decided by a very simple geometrical exposition given by Hamberger,* which we here present with some modification.

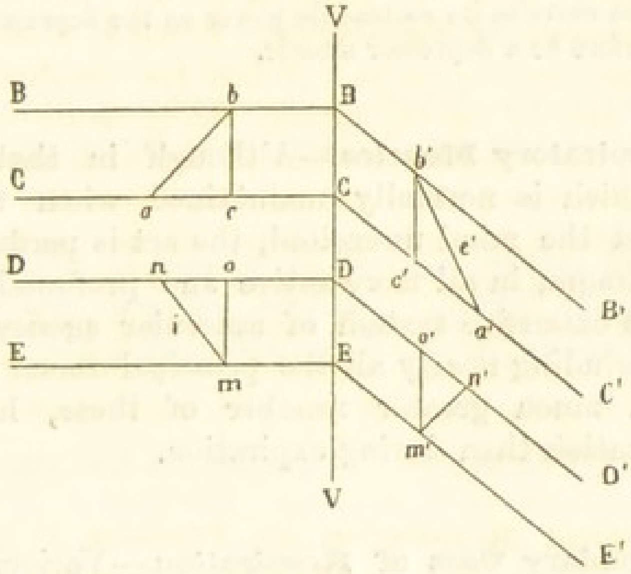


Fig. 355.

Let V V, fig. 355, represent the vertebral column, B B, C C, D D, &c., the ribs when elevated ; and B B′, C C′, D D′, &c., the ribs when depressed. Let *a b* represent a fibre of an external intercostal, and *m n* one of an internal. Let *a′ b′* represent the same external fibre, and *m′ n′* the same internal fibre, when the ribs are depressed. Now, it will be very easy to show by the most simple geometrical principles that *a′ b′* is longer than *a b*, and *m′ n′* shorter than *m n*.

To prove this, let *b c*, *b′ c′*, *m o*, and *m′ o′* be drawn severally parallel to V V. It will then be evident that all these four lines will be equal in length to B C and D E, and therefore to each other. Now, that being the case, since B *b* is parallel to C *a* and B *b′* to C *a′*, and since B *b* = B *b′*, we shall have C *c* = C *c′*, and consequently *c a* = *c′ a′*.

Now we have two triangles *a c b* and *a′ c′ b′* having their sides *a c* and *c b* = respectively to *a′ c′* and *c′ b′*, while the angle at *c* is right and that at *c′* obtuse ; consequently the base *a b* must be less than the base *a′ b′*, for the same reason that if the legs of a compass be placed at right angles its points will be less distant from each other than when they are open to an obtuse angle.

* Dissertatio de Respirationis Mechanismo et Usu Genuino.

In the same manner exactly it may be proved that in the triangles *m o n*, *m′ o′ n′*, the sides *m o* and *o n* are respectively = to the sides *m′ o′* and *o′ n′*; but since the angle *o* is right, while the angle *o′*, is acute, the side *m n* opposite to *o* must be less than the side *m′ n′* opposite to *o′*, for the same reason that if the legs of a compass be opened at right angles the distance between its points will be greater than when they are opened to an acute angle.

Now, this being understood, the function of the external and internal fibres will be rendered apparent. The external fibre *a′ b′*, when the ribs are depressed, being longer than it is when they are elevated as at *a b*, it follows that on the elevation of the ribs the external intercostal muscle must exercise its contractile power, and consequently must be an elevator; but since, on the contrary, the internal fibre *m n*, when the ribs are elevated, is longer than when they are depressed, as at *m′ n′*, the internal intercostal must exercise its contractile power on the depression of the ribs, and must therefore be a depressor muscle.

542. **Respiratory Muscles.**—Although in that gentle respiration which is normally maintained when the body is quiescent and the mind unexcited, the act is performed chiefly by the diaphragm, in all more active and profound respirations a much more extensive system of muscular agency is brought into play, including nearly all the principal dorsal and pectoral muscles. A much greater number of these, however, act during inspiration than during expiration.

543. **Secondary Uses of Respiration.**—Various physiological acts depend upon the respiratory functions. It is by the force of air voluntarily confined and compressed within the thorax, combined with the contractile force of the diaphragm and abdominal muscles, that matter is ejected from the stomach in the act of vomiting,* and from the abdomen and its contents in acts of defecation, micturition, and parturition. The atmospheric pressure, rendered effective by internal rarefication, is engaged in projecting liquids into the stomach in the act of drinking, and the pressure of the lungs when inflated upon surrounding parts produces important effects upon the motion of the blood in the veins. All the varieties of vocal phenomena are results of respiratory action, including the whole art of singing. Yawning, sobbing, sighing, hiccoughing, laughing, coughing, spitting, expectorating, sneezing, and snoring, are severally effects of various modifications of expiration.

* P. A. Beclard, Legallois, and Magendie, illustrated this phenomenon by some remarkable experiments, for a brief account of which see J. Beclard's Physiologie, p. 65.

544. **Sighing** consists in a deep inspiration, in which a more than usual volume of air is slowly inspired : it is an action, as is well known, often produced by strong mental affections, but the want of such inspiration is also often produced by the feebleness or imperfection of the normal action of the respiratory functions.

545. **Yawning** is an inspiration still more profound than sighing, accompanied by a nearly involuntary and spasmodic contraction of the muscles of the lower jaw, and of the velum palati, or that part of the palate of the mouth which closes the passage between the mouth and the throat.

546. **Laughter** consists of a rapid series of interrupted actions of expiration produced by convulsive contractions of the diaphragm.

547. **Sobbing**, though it arises from mental causes contrary to those which produce laughter, differs nevertheless from laughter in nothing important so far as it relates to its physical cause.

548. **Lungs and Air-passages.**—The immediate apparatus of respiration to which the mechanism of the thorax, already described, is accessory, consists of the trachea or windpipe, the two bronchi with their ramifications, and the lungs.

549. **The Form of the Lungs** and their position relatively to the heart and its appendages are represented in fig. 312 ; the lungs, however, being pushed apart so as to show the heart and blood-vessels. In their natural position the lungs envelop these latter. Their external form corresponds with that of the interior surface of the sides of the thorax, against which they are placed, and to which they are fitted.

550. **The Trachea** (*a*, fig. 313) is a cartilaginous pipe of annular structure, commencing at the upper part of the throat and bifurcating at a point a little below the neck, opposite the third dorsal vertebra. By its bifurcation it forms two smaller tubes, which pass to the right and left into each lung. These tubes are called the *bronchi*.

551. **The Bronchi.**—The structure of the bronchi is similar to that of the trachea. Both are maintained permanently open

by a mechanical arrangement similar to that of a flexible hose for conducting water, the collapse of which is prevented by rigid rings surrounding it from point to point.

552. **Air-cells and Intercellular Passages.**—The bronchi after entering the lungs diverge into innumerable ramifications, which become more and more minute, pervading every part of the pulmonary structure. They lead to minute cavities called *intercellular passages*, and these last after numerous bifurcations terminate each by a cœcal extremity, cul de sac, or *air-cell.*

553. It will be understood from this that the air which enters the lungs has not, properly speaking, any circulation there. After entering through the trachea, and passing through the bronchial tubes and the intercellular passages, it inflates the terminal air-cells, which, being closed at their extremities, arrest its further progress. After a full inspiration, these air-cells and intercellular passages are inflated and distended. During the succeeding expiration a part of the air in them, but a part only, is expelled. Even after the most forcible and long-continued expiration a considerable quantity of air remains in the cavities of the lungs. The alternate process of inspiration and expiration is not therefore the alternate inflation and evacuation of the lungs, but merely one in which they are alternately more or less distended by air. It is computed that the total quantity of air contained in the lungs is about 300 cubic inches when fully inflated ; and since the average volume of air expired is about 30 cubic inches, it follows that even after expiration the lungs contain 270 cubic inches of air, so that the effect of respiration is the alternate increase and diminution of the air contained in the lungs by about one-tenth of its whole volume.

554. **Dimensions of Air-cells and Passages.**—In an adult, the dimensions of the smallest ramifications of the bronchial tubes vary from the thirtieth to the fiftieth, and those of the air-cells from the seventieth to the two hundredth of an inch.

555. **Sanguiferous Capillaries.**—The walls of the air-cells and internal passages are covered with a net-work of sanguiferous capillaries of admirable richness. These communicate on the one side with the pulmonary veins, and on the other with

the pulmonary arteries. It is in these that the blood undergoes that change by which it is arterialised.

556. **Physiological Effects of Respiration.**—Having explained generally the mechanical principles engaged in the play of this important function, it now remains to notice the physiological effects which result from it.

557. **Constituents of Atmosphere.**—The atmosphere, which is the immediate object of respiration, is a fluid, which, when pure, consists of two gases ; one, nitrogen or azote, and the other oxygen, combined together either by mere intermixture, or by the most feeble chemical combination, if indeed any such combination exist at all. A hundred cubic inches of the pure atmosphere consists of 79·10 of azote, and 20·90 of oxygen.

The atmosphere also holds in suspension a very variable proportion of the vapour of water. Sometimes it is completely saturated, but often in a comparatively dry state.

The quantity of vapour necessary to produce saturation increasing with the temperature, the air will be saturated in cold weather by a quantity of vapour which would be quite insufficient to produce saturation in warm weather. At all times, however, the atmosphere is subject to extreme variations relatively to its point of saturation, the quantity of vapour dissolved in it being generally much less than would produce saturation.

The atmosphere also contains at all times diffused throughout it more or less carbonic acid, but the quantity of this constituent is never so considerable as to require notice here.

558. **The Analysis of Air expired** in respiration shows that 100 cubic inches of it contains only 16·03 cubic inches of oxygen ; but it contains, besides this, 4·26 cubic inches of carbonic acid not present in it when inspired. It follows, therefore, that in the lungs the 100 cubic inches of air have been deprived of 4·87 cubic inches of oxygen, and have received 4·26 of carbonic acid.

559. **Carbonic Acid expired.**—Carbonic acid is a gas produced by the chemical combination of carbon and oxygen, and the quantity of oxygen it contains has exactly the same volume as the carbonic acid itself. The 4·26 cubic inches of carbonic acid expired consequently contains 4·26 cubic inches of oxygen. Although, therefore, 100 cubic inches of air respired have apparently lost 4·87 cubic inches of oxygen, they have in reality received in a state of combination, in the carbonic acid, 4·26

cubic inches of that gas. A small quantity of oxygen, amounting to the difference between 4·87 and 4·26 cubic inches—that is, to 0·61 cubic inches of oxygen,—would appear from this to have remained in the lungs.

560. **Aqueous Vapour expired.**—It must be observed, however, that the air expired contains more watery vapour than was included in the air inspired ; and water being formed by the combination of oxygen and hydrogen in a certain definite proportion, the missing 0·61 cubic inches of oxygen may be accounted for by the quantity of that gas expired in a state of combination in aqueous vapour.

561. It appears, therefore, that in the act of respiration the organism expels a certain quantity of carbon and hydrogen, and receives a quantity of oxygen, which, by combination with this carbon and hydrogen, would form carbonic acid and water.

562. **Various Theories of Respiration.**—Much difference of opinion still prevails among physiologists as to the phenomena which take place in the organism, the ultimate result of which is the physical change operated on the air during its continuance in the lungs, and as to the manner in which it is instrumental in arterialising the blood. They are not even agreed as to the physical difference between the nutritive arterial and the unnutritive venous blood. The experiments adduced by some in support of one hypothesis are questioned or rejected by those who favour another ; and the consequence is, that the theory of respiration is in a very unsatisfactory state, as a subject of elementary instruction.

563. What is certain is, that the blood in the course of the greater or systemic circulation loses its vital and nourishing virtue, and that this virtue is restored to it in the lesser or pulmonary circulation. But what the physical changes are by which that physiological virtue is lost in the one circulation, and recovered in the other, is not so clear.

564. **Theory of Lavoisier.**—Carbon and hydrogen are eminently combustible, and the phenomenon of combustion, attended with a great evolution of heat, is produced by their combination with oxygen. This obvious chemical principle led some chemists and physiologists to conclude that a slow combustion takes place in the lungs, by the combination of

a portion of the oxygen of the air inspired with a corresponding quantity of carbon and hydrogen expelled from the blood through the membrane of the pulmonary capillaries; and this combustion is regarded accordingly as the source of animal heat.

According to this theory, the blood in fact receives nothing from the air inspired, the operation which is effected in the lungs being simply excretory. The carbon and hydrogen expired in combination with the oxygen previously inspired would therefore be merely excrementitious.

Against this theory several objections are urged. First, that if the lungs were the seat of such a combustion, their temperature would be more elevated than that of other parts of the body, which is not found to be the case; and secondly, that the fact of the escape of hydrogen and the vapour of carbon through the tissue of the lungs to combine with the oxygen of the air inspired is purely hypothetical, and altogether unproved.

This theory was supported by Lavoisier, Laplace, and Prout.

565. **Theory of Davy.**—Another theory, advanced by Sir H. Davy, and adopted by chemists generally, is, that the air respired, or a portion of it, enters the blood which circulates in the pulmonary capillaries, where a part of its oxygen combines with the red blood corpuscles, and where carbonic acid is formed, which, with nearly the whole of the azote, is again expelled and expired. Sir H. Davy supposed that a certain portion of the carbonic acid respired is evolved in the blood itself.

According to this theory, the combustion which produces animal heat takes place in the blood during its passage through the lungs; and it receives some countenance from a fact discovered by Dr. J. Davy, that the arterial blood in the left auricle and ventricle has a temperature which exceeds that of the venous blood in the right auricle and ventricle by 1° or $1\frac{1}{2}$° Fahrenheit.

566. **Other Hypotheses.**—A third hypothesis,—admitting the formation of carbonic acid, either in the lungs themselves, according to the first hypothesis, or in the blood which passes through them, according to the second,—ascribes the arterialising property to the surplus 0·61 per cent. of oxygen not thus combined, and

the aqueous vapour expired to the ordinary physical evaporation which must, at all events, take place from a moist surface, such as that of the air-cells of the lungs or bronchial tubes, especially at the elevated temperature at which they are maintained.

This hypothesis is favoured by the result of experiments of Collard de Martigny, in which it was shown that the same quantity of aqueous vapour was expired when the air respired was hydrogen, or any other gas from which oxygen is absent.

This would be conclusive, provided the air actually included in the lungs, during such experiments, contained no oxygen. But this is not—and never can be—the case; a large quantity of atmospheric air always remaining in the lungs even after the strongest expiration.

567. **Hypothesis of Magendie.**—This physiologist ascribed the production of watery vapour from the lungs, not to mere physical evaporation from the moist surfaces of the lungs, but to transpiration from the blood through the pulmonary tissues, like the aqueous transpiration from the skin; and he supported this hypothesis by experiments proving that such pulmonary transpiration is always increased when water, having the temperature of the blood, is injected into the veins.

This physiologist also ascribes the redness of the arterial blood to the excess of oxygen absorbed over that which is expired in combination with carbon. This receives confirmation from the experiments which show that, when venous blood and air are agitated together, the blood acquires the arterial characters, and the volume of oxygen absorbed always exceeds that of the carbonic acid evolved.

568. **Lagrange and Hassenfratz** advanced a fourth theory, in which the oxygen received by the arterialised blood in the lungs is assumed to be transported through the circulation, and that its combination with the carbon, excreted from the system, takes place in all the capillaries of the organism. The carbonic acid thus produced is transported in the current of venous blood to the pulmonary capillaries, where it is dismissed and expired in respiration.

In this theory the arterial blood is assumed to be charged with oxygen and the venous with carbonic acid. It has been extensively adopted by physiologists, and is countenanced by the experiments of Vogel, Home, Brande, Scudamore, and

Collard de Martigny, which show that venous blood yields carbonic acid, as well as by those of Sir H. Davy, which show that arterial blood yields oxygen when its temperature is raised. It is also consistent with the equal diffusion of the animal heat through the organism.

Nevertheless, certain high authorities dispute the experiments on which this theory is based, denying that carbonic acid is educed from venous, or oxygen from arterial blood.

569. **Another Theory.**—According to a fifth theory, the carbonic acid exhaled in the lungs is supposed, like all other secretions, to be evolved from the ultimate elements of the blood itself. The secretion of gases in the air-bladder of fishes is adduced in support of this hypothesis, which, being admitted, would involve the supposition that the carbonic acid might be excreted in the capillaries quite independently of the presence of any oxygen in the blood which circulates through them.

This hypothesis is based upon the statement, that cold-blooded animals exhale carbonic acid in a medium in which no oxygen is present.

570. **Experiment of W. Edwards.**—Some years ago the following experiment was made by Mr. William Edwards: that physiologist placed in a receiver, filled with nitrogen or any other gas incapable of supporting life, and which did not contain oxygen as a constituent, an animal—such as a frog—capable of resisting asphyxia for a considerable time. Upon analysing the gas after a certain interval, he found that it contained exactly the same quantity of carbonic acid, as if the animal had been supplied during the interval with pure atmospheric air. Now, in this case, it is impossible to ascribe the production of the carbonic acid to the combination of oxygen with carbon in the lungs in the act of respiration, since the air, inspired by the animal, contained no oxygen; carbonic acid, therefore, expired, must have been previously contained in the venous blood, and disengaged from it in passing through the lungs.

571. **Experiments of Magnus.**—In further confirmation of these views, it has been shown, that there exists always in solution in the blood a certain quantity of carbonic acid, as well as a small proportion of oxygen and azote. It further appears, by

the researches of Magnus, an eminent chemist, of Berlin, that the blood has the property of dissolving a certain quantity of all gases with which it comes in contact, and that whenever, being already impregnated with any gas, it absorbs another, it disengages the former which gives place to the latter. Thus, if venous blood be agitated in a receiver filled with hydrogen, it will dismiss the carbonic acid with which it is already impregnated, and will dissolve a corresponding portion of the hydrogen; and if a like experiment be made in a receiver containing oxygen, a like result will ensue, the carbonic acid being disengaged and the oxygen absorbed; and in this case, the blood will be converted from venous to arterial, its colour being changed from dark to bright red. In this experiment, therefore, all the principal phenomena which take place in the lungs under the influence of the vital principle, would seem to be reproduced merely in virtue of the property which the blood possesses of dissolving successively different gases, and, at the same time, disengaging those with which it had been previously impregnated.

572. **Objection to these Answered.**—It might be objected to the inferences drawn from these experiments, that in the pulmonary phenomena the blood does not come into immediate contact with the air inspired, as is the case when blood is agitated, as described above, in a receiver filled with the gas on which it is intended to act. But this objection is answered by another experiment, in which it is shown that the principle of exosmose will cause the same phenomena to be produced, when the blood and the gases which mutually react are separated by an organic membrane. Thus, if a bladder filled with venous blood, and well closed, be suspended in a receiver filled with pure oxygen, the oxygen will pass into the bladder, and the carbonic acid pass out of it through its texture by the principle of endosmose and exosmose. The blood will be converted into arterial blood, and will become bright red, and the carbonic acid dismissed from it will be found in the receiver.

In this experiment, therefore, all the conditions of the pulmonary phenomena are faithfully reproduced, with the exception that the membrane—of which the pulmonary capillaries are formed—is, as may well be supposed, much more permeable by the gases than the membrane of any bladder which can be used in such an experiment.

573. **Source of Animal Heat.** — Whatever theory be adopted, it is evident that one of the phenomena attending respiration is a slow combustion produced either locally or generally in the system, and that the interchange of gases between the air inspired, and the blood circulating in the pulmonary capillaries, is accessory to this, either as an immediate cause, or a preliminary process. This combustion is the source of animal heat.

574. **The average Consumption of Oxygen** per day by an adult in respiration is easily computed by the data which have been given by the observations already stated.

The average volume taken into the lungs at each respiration being 30 cubic inches, and the number of inspirations per minute being 18, it follows that the average volume of air respired is 540 cubic inches per minute, 32400 cubic inches per hour, and 777600 cubic inches, or 450 cubic feet per day. But it has been already stated that the proportion of oxygen absorbed is 4·87 per cent. of the air respired. It follows, therefore, that this quantity per day amounts to 22 cubic feet, and consequently it appears that each full-grown man consumes daily an average volume of 22 cubic feet of oxygen.

575. It has been already explained, that of the total volume, 4·87 per cent. of oxygen, which disappears in respiration, 4·26 per cent. is expired combined with carbon. This proportion of 450 is 19·17 cubic feet. Now, by the known composition of carbonic acid, 19 cubic feet of that gas will contain 4332 grains, or about 10 oz. of carbon. Thus, it appears, that an average full-grown man imparts to the atmosphere daily 10 oz., or six-tenths of a pound of carbon.

576. **Vegetables consume the Carbon evolved by Animals.**—Although the inferior orders of animals have a respiration much less active than that of the human race, it will, nevertheless, be apparent, that the quantity of oxygen thus converted into carbonic acid, by the countless number of animals which are spread over the surface of the earth, must be so enormous, that the entire atmosphere would very soon be robbed of its oxygen, if Nature had not provided adequate means for its reproduction. These means, as always happens in the economy of creation, are admirably adequate. While the animal world consumes oxygen and evolves carbonic acid,

the vegetable world, which has a respiration of its own, consumes carbonic acid and evolves oxygen; and the quantity of oxygen consumed by the one is so exactly equal to the quantity produced by the other, that the proportion of oxygen to azote in the general atmosphere is maintained without the slightest variation. If the animal world were to consume more oxygen than the vegetable world produces, the necessary consequence would be that the proportion of oxygen in the atmosphere would be gradually diminished and finally exhausted, and the animal world would cease to exist. If, on the contrary, the vegetable world were to produce more oxygen than the animal would consume, the proportion of oxygen in the atmosphere would be continually augmented, animal life would be unduly stimulated, a state of unhealthy intoxication would ensue, which would abridge the duration of life of all species, and at length extinguish the animal kingdom as effectually as would the total absence of oxygen.

Although the respiration of vegetables produces, on the whole, a supply of oxygen to the atmosphere, this production is not continuous or incessant. During the day, and under the stimulus of light, the leaves of plants absorb carbonic acid, and decompose it, dismissing the oxygen and incorporating the carbon with their own substance; during the night, however, the necessary stimulus of light being removed, the absorption of carbonic acid is discontinued, and, on the contrary, that gas is emitted, but in very much less quantity than that in which it was absorbed during the day. The absorption, therefore, on the whole, greatly predominates over the emission, so as to maintain an equilibrium in the constituents of the atmosphere, as above stated.

577. **Plants injure the Atmosphere at Night.**—It may be useful to observe here, that the circumstance just mentioned, of plants emitting carbonic acid at night, renders them unhealthy companions in close rooms at that time, where their presence has the same effect, differing only in degree, as that of a pan of burning charcoal. On the contrary, during the day, their presence has a tendency to improve the atmosphere of rooms, by absorbing the carbonic acid produced by respiration, and replacing it by a corresponding volume of oxygen. Persons who love flowers, should therefore, keep them in their rooms only during the day, being careful to have them removed after sunset.

578. **A Relation between Respiration and Bodily Activity** is found to prevail, so that the quantity of air consumed, and carbonic acid expired, may be said to be, cæteris paribus, proportional to the vivacity of the movements. Thus, animals of slow and sluggish habits have a less active respiration than those which move more rapidly and constantly. A frog consumes less air than a butterfly, though its body contains some hundred times more matter.

579. **The Respiration of Persons of Sedentary Habits** consumes less oxygen than that of persons who are more active and laborious. When we walk fast or run, we breathe with greater frequency, and often so much so, that we find ourselves unable to supply the lungs with air as rapidly as the body requires, and we are what is called out of breath. All this is the necessary and obvious consequence of the relation between the functions of motion, nutrition, circulation, and respiration. All corporeal motion, as has been already explained, being attended with more or less waste and wear of the bodily substance, this waste and wear must be immediately replaced by the blood, and the blood must receive from the food what it thus loses. But this supply cannot be fitted to restore the waste of the blood, until it has received a corresponding supply of oxygen from the lungs. Thus bodily activity requires increased rapidity of circulation, and increased rapidity of circulation requires increased activity of respiration.

580. **Gradual Change of Matter Comprising the Body.**— While fresh portions of matter, derived immediately from the blood and more remotely from the food, are constantly incorporated with all parts of the living body, a contrary process is carried on, by which other portions of used-up and worn-out matter are rejected from the same organs and expelled from the body. A multitude of experiments and observations demonstrate this continual and gradual change of the matter of which the animal body is composed. Thus, while the bones are enlarged by the deposition of fresh particles, the absorption of the matter of which they were previously composed is, at the same time, going on within them, so that, after the lapse of a certain interval, the entire matter composing them must be changed. In the same manner, the skin which covers the body externally, and the mucous membrane which clothes it

internally, are subject to a gradual renewal ; a process which, in fine, is common to all parts of the organism, although the changes are produced in different parts with greater or less celerity.

581. **Interval at which the Change is Complete.**—Physiologists have therefore inferred that within a certain limited interval of time the entire body is changed, not a particle found in it at the end of such an interval being identical with any which composed it at the commencement. What this interval of complete change is has not been certainly ascertained. It was long assumed to be seven years, but more recent authorities assign to it a much shorter period, and it is even inferred by eminent contemporary physiologists that the whole body is renewed in an average period not exceeding thirty days.*

An apparent objection to this doctrine is presented by the fact that scars and other injuries which deface the surface of the skin remain as permanent marks through life, even when the injury occurs in childhood. This, however, is easily explained. The modification which the structure suffers by the wound after cicatrisation is permanently maintained, although the particles which form the modified structure are subject to constant change.

582. **Food supplies Carbon.**—It appears, therefore, that the aliment taken into the animal organism is required to fulfil two distinct purposes: first, to supply the organised matter which is necessary to replace the waste of the body in adults, and not only the waste but the growth in the young ; and, secondly, it must supply carbon and hydrogen in sufficient quantity to convert the oxygen of the arterial blood into carbonic acid and water.

583. So imperious is the organic necessity for the conversion of the oxygen of the blood into carbonic acid, that if an animal be not supplied with food which contains a sufficient quantity of carbon for this purpose, the surplus oxygen will rob the tissues and organs themselves of the necessary quantity : thus the body will lose a part of its constituents which will not be replaced by the food, and if this state of things be continued the body will waste away.

* See Johnston's Chemistry of Common Life, where, however, the authority for this very short period is not quoted.

584. **Surplus Carbon in the Food produces Fat.**—If, on the other hand, the food taken into the system contain more carbon than is necessary to combine with the oxygen of the blood, the surplus will be deposited in the organism in the shape of fat, a substance, the analysis of which shows that its chief constituents are carbon and hydrogen. If, after an accumulation of this fat, the food undergo a change in consequence of which it will contain an insufficient proportion of carbon and hydrogen, the oxygen of the blood will immediately address its exigencies to the accumulated fat, which it will gradually consume by combining with the carbon and hydrogen, which are its chief constituents, and the animal will again become lean.

585. **Sedentary Habits produce Corpulency.**—These principles will easily explain why sedentary habits and rich diet produce corpulency ; and why, on the other hand, active and laborious habits prevent that state. It has been already explained that sedentary habits are necessarily attended with slow and feeble respiration ; less oxygen, therefore, passes through the circulation, and proportionally less carbon and hydrogen are absorbed from the system. The large surplus of these, supplied by a rich diet, is converted into fat, and hence corpulency ensues. But if, while such a diet be continued, active habits be adopted, and much bodily exercise and labour take place, the circulation is stimulated, a greatly increased quantity of air passes through the lungs, a proportionally increased quantity of oxygen is conveyed through the blood, and a corresponding consumption of carbon and hydrogen ensues, so that the whole of these principles contained in the food will be absorbed, and the accumulation of fat and corpulency be prevented.

586. **Corpulency checked by Exercise and Labour.**—It is well known that a tendency to corpulency can always be checked by perseverance in a regular and sufficient course of bodily exercise. We have seen the case of a young man who had become corpulent, being reduced to the average condition of body by the mere exercise of walking, having commenced by walking five miles a day, and adding a mile to the distance daily, until his promenade was augmented to twenty miles.

In fine, it is evident, from what has been explained, that in every case a just relation should be maintained between the quantity and quality of aliment, and the quantity of bodily exercise or labour.

587. **Use of Fat.**—Although corpulency is to be avoided, a certain amount of fat is necessary in the system. Its principal uses are mechanical. It surrounds the organs like an elastic cushion, so as to protect the more delicate parts from sudden and injurious shocks. Thus, the eyeball, one of the most important and delicate of the organs of sense, is deposited in a socket, surrounded with a thick stratum of fat. The soles of the feet, upon which the whole weight of the body rests, and which, in locomotion, are subject to frequent concussion and pressure, are protected by a cushion of fat, which breaks the shocks which would otherwise take place between the feet and the ground, in the same manner as do the buffer-cushions which are placed between the carriages of a railway train.

There is another physical quality of fat, which renders it of considerable utility in the animal economy; it is nearly a non-conductor of heat, and as it is generally collected in a superficial stratum, investing the organs, it prevents the undue escape of heat, and keeps the body warm; it thus performs the part of a blanket or clothing, and it is found accordingly that fat persons are less chilly than thin.

588. **Corpulency is developed chiefly in the Abdomen.**—Fat does not accumulate with equal facility in all parts of the system, it is deposited, on the contrary, in some, by preference to others, and one of the regions where it has most tendency to accumulate, is that part of the peritoneum which envelopes the intestines, the folds of which, called the mesentery, have been already noticed. It is the accumulation of fat in these parts that produces the enlargement of the abdomen, observed in corpulent persons.

589. **Food supplies the Fuel.**—Slow internal combustion is, as we have already explained, the origin of animal heat; and while we are to consider a part of the food we consume as nourishment for the body, we must regard another part as

fuel, destined to maintain that internal fire, which supplies the warmth necessary to the maintenance of animal life.

590. **Warm and Cold-blooded Animals.**—This internal source of heat is common to all animals, but they do not all possess it in the same degree. After what has been stated, it will be apparent that the animal heat will be proportionate to the activity of respiration; and it is accordingly found that while the bodies of species, whose respiration is active, are maintained at a temperature considerably more elevated than that of the surrounding atmosphere, the temperature of those having less active respiration is much lower, and in some not greater than that of the medium they inhabit.

If a bird and a fish of equal weight be placed in a calorimeter,* it will be found that in two or three hours a pound, or upwards, of the surrounding ice will have been liquified by the heat proceeding from the bird, while no sensible quantity will have been melted by that proceeding from the fish.

This great difference between the quantities of heat developed in the internal organisation has supplied the ground for the division of animals into two classes, called *warm-blooded* and *cold-blooded*, the former including those classes which maintain in their bodies a temperature but little affected by that of the surrounding medium, and generally above it; and the other, those which have a temperature not exceeding that of the fluid they inhabit, and varying with it.

The temperature of different species of mammalia varies from 97° to 104°, that of birds is about 108°.

591. **Hibernating Animals.**—Mammalia, and birds generally, maintain in their bodies one invariable temperature at all seasons of the year, the loss of heat by cutaneous evaporation in the cold season being apparently so much diminished as to compensate for the greater quantity of heat lost by radiation. There are some species, however, which cannot produce more heat than is sufficient to raise their temperature from 20° to 26° above the temperature of the surrounding atmosphere. It follows, therefore, that while in the hottest part of summer their temperature is nearly the same as that of other warm-blooded animals, it falls to a much lower point in the cold season, and whenever the depression of temperature attains a certain limit, the circulation and respiration decrease in

* Hand-book of Nat. Phil.; Heat, § 402.

frequency and energy, so that the animal falls into a state of torpor, or lethargic sleep, which continues until the temperature of the atmosphere is sufficiently elevated to re-establish the activity of the vital functions. Animals which are thus subject to a periodical lethargy, are called hibernating animals, and may be considered as holding a place intermediate between warm-blooded and cold-blooded animals. The marmot (fig. 356), the bat, and the hedgehog belong to this class. A large store of fat is formed in some of these to supply the necessary internal combustion during the hibernation.

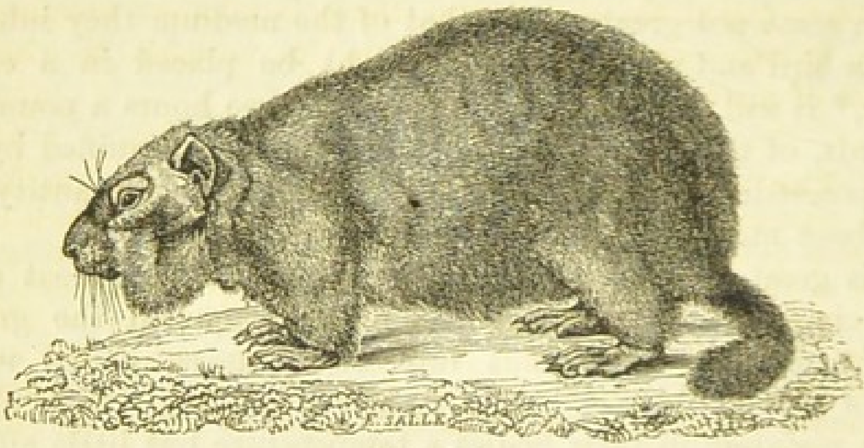


Fig. 356.
MARMOT.

592. **The Respiration of the lower Animals**, like that of man, consists mainly of the interchange of gases between the blood and the atmosphere. At all points where the blood is separated from the air only by membranes or thin tissues, this interchange takes place, and consists of the exhalation of carbonic acid and the absorption of oxygen. In the superior classes generally this interchange is localised in special organs traversed by the whole mass of the circulation and kept in a state of permanent humidity, while in those which hold a lower place in the scale of organisation, respiration often takes place either internally or externally upon the entire tegumentary surfaces.

593. **Respiration of Mammifers.**—The function of respiration is performed in this class by lungs which are altogether analogous to those of man. The cutaneous respiration, which is feeble in man, is still more so in the lower mammifers, owing

to the fact of their tegumentary envelope being generally covered with hair or wool.

594. **The Respiration of Birds,** like that of mammifers, is performed by lungs, but it is attended with some peculiarities connected with their habits. Instead of filling the thoracic cavity, the lungs properly so called do not occupy more than a seventh or eighth part of it, being confined to the dorsal part of the pectoral cage, and applied against the vertebræ by a membranous and fleshy coat, which, being fixed on each side to the ribs, presents its concavity towards the sternum and its convexity towards the lungs. Independently of this, which is sometimes called the diaphragm, there is another membranous muscle, which corresponds nearly in its position to the diaphragm of mammifers.

595. **The Air Sacs.**—This second diaphragm, like the former, is not separated completely from the respiratory organ, which is prolonged so as to form a communication with certain air sacs formed by membranous cavities. Of these sacs four are, like the lungs, included in the chest between the two diaphragms, and are denominated the *anterior and posterior diaphragmatic sacs.* Another air sac, called the *anterior thoracic sac,* is situated also in the pectoral cavity, but outside the diaphragms. It fills the interior part of the chest behind the sternum. Other air sacs are situated outside the thoracic cavity. Two are called the cervical or interclavicular, and two others the abdominal sacs.

596. **Bronchial Tubes.**—These several air sacs have no communication with each other; but as each communicates directly with the bronchi, they may be regarded, in a certain sense, as continuations of the lungs. The bronchial tubes, which form the communication between them and the lungs, are of considerable calibre. The principal divisions of the trachea, instead of burying themselves in the lungs, and ramifying there before passing to the air sacs, traverse the surface of the lungs, and communicate directly with those sacs. It may be added that in the lungs of birds the cartilaginous rings of the bronchial tubes are generally incomplete, while those of the trachea are more complete than in mammifers. The bronchial tubes of birds differ from those of man and the mammalia generally, inasmuch as instead of being *culs de sac,* in which the movement of the air is arrested, they are open tubes, which anastomose with each other, and form in the lungs a network of canals, through which the air circulates in a manner analogous to the movement of the blood in the veins. The air which has traversed this bronchial system, and has arrived at the air sacs, proceeds still further, since some of these sacs communicate in many species of birds with the cavities of the bones. It is thus that the air of the cervical sacs penetrates into the cervical and dorsal vertebræ, and into the vertebral ribs,—that the air of the thoracic sacs is introduced into the clavicle, the sternum, the scapula, the sternal ribs, and the humerus,—that the air of the abdominal sacs communicates

with the sacrum, the coccygeal vertebræ, and with the iliac and thigh bones.

The diaphragmatic sacs included with the lungs between the two diaphragms have no communication, however, with the bones.

597. It must be observed, that such communication between the air sacs and the bones do not exist in all birds, being only observed in those endowed with the higher powers of flight. Many gallinaceous and web-footed birds, with others of feeble flight, have such communications either in a very partial degree or not at all.

598. **The Movements of Inspiration** are effected in birds by the elevation of the ribs and sternum and the contraction of the diaphragms. The superior diaphragm, diminishing its concavity, draws the lung forward, and increases its diameter measured before to behind. The inferior diaphragm, lowering itself, increases the vertical diameter of the pulmonary cavity. The diaphragmatic sacs which are included between the two diaphragms also contribute, even more energetically than the lungs themselves, to draw in the air. Their capacity is increased at the moment of inspiration by the separation of the two diaphragms. The air sacs, which are situated outside the diaphragms, and consequently beyond the limits of the expansive power, do not act as inspirators at the moment of the contraction of the diaphragms. The diaphragmatic air sacs, being dilated, draw not only the air from without through the trachea, but also from the other air sacs in communication with them, by the intervention of the lungs. It follows from this, that the movements of inspiration of birds not only make the external air penetrate into the lungs and the pulmonary sacs, but also produce partial inflation in the other air cells. On the other hand, at the moment of expiration, the air contained in the diaphragmatic cells, compressed at once by the diminution of the thoracic cage and by the return of the two diaphragms, does not entirely escape by the lungs and the trachea, but passes in part into the other air cells. In this manner, and by this double play, the air which circulates in the most distant regions of the respiratory organs is agitated and renewed.

599. The most vascular parts of the respiratory apparatus of birds is the lungs themselves, and it is there more especially that the interchange of gases essential to respiration takes place. The air sacs and the cavities of the bones, much less vascular

than the lungs, have more especial relation to the mode of locomotion peculiar to the bird, and are designed principally to diminish its specific gravity. But a certain supplementary respiration also takes place in their interior.

600. The distribution of air cells in different species of birds has a distinct relation to the power of flight. Thus in the eagle they are found in all the bones, while in the penguin they are excluded from all or nearly so. The air is generally found to extend most into the bones which are chiefly used for locomotion, as in the case of the bones of the ostrich.

It is mainly to the high state of development of the function of respiration in this class that the higher temperature of their blood is to be ascribed.

601. **View of the Lungs of Birds.**—A general view of the lungs of a bird is given in fig. 357.

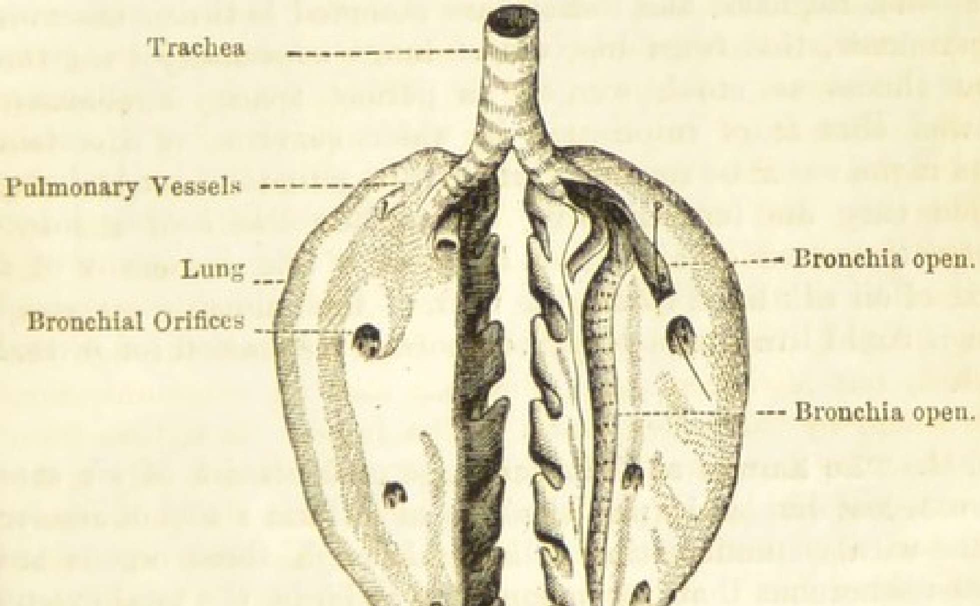


Fig. 357.

LUNGS OF A BIRD.

602. **The Respiration of Reptiles.**—The respiration of reptiles is much less active than that of birds or mammifers, and to this feebleness of the respiratory functions is to be ascribed the circumstance of the low temperature of their blood. Most reptiles respire in the air by lungs; some, however, which, when full grown, have pulmonary respiration,

breathe like fishes, by gills, in the first period of their growth. Frogs present an example of these.

603. **Amphibious Reptiles** breathe by lungs, and are, when immersed in water, compelled to rise to the surface to respire the air. There are some amphibia, however, which, during the entire period of their lives, are supplied both with gills and lungs, so that they are endowed at once with the full power of aërial and aquatic respiration.

In the case of all naked reptiles which breathe by lungs and live partly in the water, the skin forms an important organ of respiration, possessing at once the character of lungs and gills. By this organ the interchange of gases and respiration can be produced as well by the contact of water as by that of air, as has been proved by numerous experiments. It is even probable that with some reptiles cutaneous respiration is as active as pulmonary.

Messrs. Regnault and Reiset have observed in their numerous experiments, that frogs deprived of lungs consume in a given time almost as much oxygen as perfect frogs. Spallanzani showed that frogs submerged in water survive for a certain time if the water be renewed, but if it be purged of air by being boiled they die immediately. Milne Edwards having intercepted the access of air to the lungs of a frog by means of a hood of oil silk fixed round the neck of the animal, ascertained that it could live thus by mere cutaneous respiration for several days.

604. **The Lungs of Reptiles** in general consist of air sacs more or less divided by partitions, so as to form a sort of areolar tissue with communicating cells. Although these organs are more voluminous than in mammifers or birds, the total extent of what may be called the respiratory surface, that is the surface through which the interchange takes place between the air respired and the blood, is considerably less. There is no diaphragm, and the thorax and abdomen form one continuous cavity. It follows that there can be no respiratory movements at all analogous to those which have been explained in the other classes. The air is consequently renewed in the lungs in a much less complete manner, being taken in at the mouth, not by inspiration properly so called, but by a sort of deglutition. The throat, dilated by its proper muscles, receives the air through the nostrils, and is then contracted by the antagonist

muscles, so that the air thus received is pressed on to the lungs.

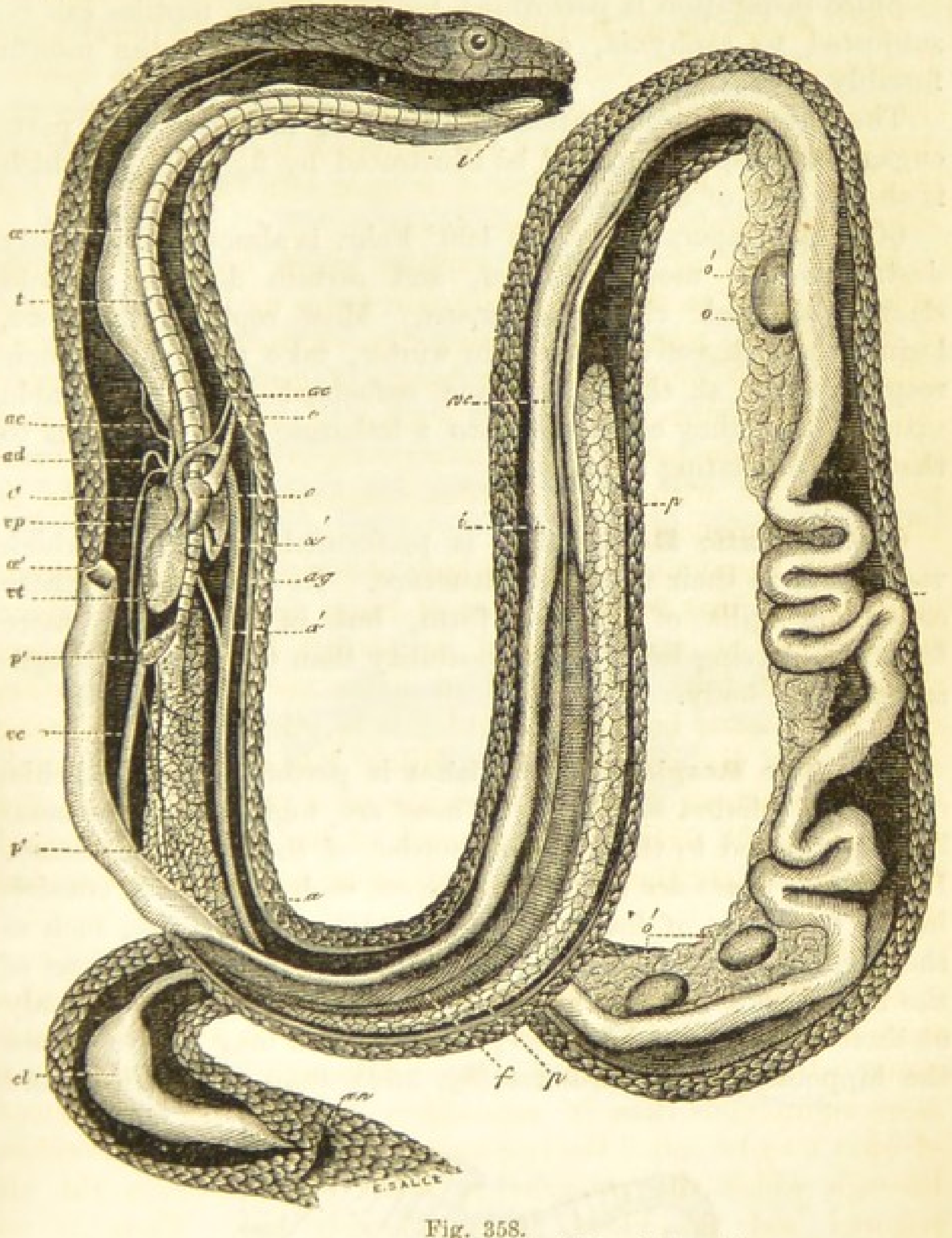


Fig. 358.
ORGANISATION OF THE ADDER (Milne Edwards).

l The tongue and glottis.
œ The œsophagus divided at *œ'*, to show the heart and surrounding parts.
i The stomach.
i' The intestine.
cl The cloaca.
an The anus.
f The liver.
o The ovary.
o' Eggs.
t The trachea, or windpipe.
p The large lung.
p' The small lung.
vt The ventricle.
c The left auricle.
c' The right auricle.
a The left aorta.
ad The right aorta.
a' The abdominal aorta.
ac Carotid arteries.
v Superior cava.
vc Inferior cava.
vp Pulmonary vein.

Expiration is performed by the elastic force of the lungs and the contractile power of the abdomen.

Since respiration is performed by deglutition, reptiles can be subjected to asphyxia, or suffocated, by keeping the mouth forcibly open.

The internal organisation of reptiles, including the parts engaged in respiration, will be illustrated by fig. 358, in which is shown that of the adder.

605. A temperature above 100° Fahr. is almost immediately destructive to most of them, and certain degrees of cold slacken all their vital phenomena. Most reptiles, therefore, losing their digestive power in winter, take no food. Their respiration is at the same time enfeebled in a remarkable manner, and they often fall into a lethargic state analogous to that of hibernating animals.

606. **Aquatic Respiration** is performed by organs which vary much in their form and structure. In some classes these consist of gills of foliated form, but in others are mere tubercles, having little more sensibility than the general integument of the body.

607. **The Respiration of Fishes** is performed by branchiæ or gills of foliated structure. These are highly vascular membranes attached to the external border of the branchial bones. In general, there are four branchiæ on each side, each consisting of two rows of leaves. Most cartilaginous fishes, such as the ray, have five, and the lamprey has seven. With most of the bony fishes the gills are of simple structure, and fixed only at their base ; but with a few, among which may be mentioned the hippocampus or sea-horse (fig. 359), they are ramified, and

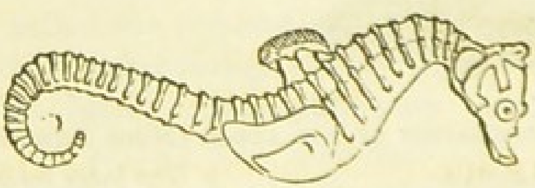


Fig. 359.
THE HIPPOCAMPUS OR SEA-HORSE.

have a resembance to feathers. In cartilaginous fishes they are generally attached to the skin at their external border, as well as to the branchial bones at their internal border.

Respiration is accomplished, not, as in land animals, by air in

its free state, but by the portion of that fluid with which the water is always more or less impregnated. The water necessary for respiration enters the mouth, and, by a species of deglutition, it is drawn in and driven through the interstices of the branchial bones. In this way it passes between the membranes forming the gills, which it washes, and then makes its exit by the orifices in which the gills are deposited.

The animal is seen alternately to open its mouth for the reception of the water, and to raise the operculum of its gills for its discharge.

In the case of fishes whose branchiæ are not attached at their exterior edge, a single opening at each side suffices for the exit of the water; but with those which have the external edge of the branchiæ attached to the skin, as many openings are necessary as there are inter-branchial spaces. Thus, in the shark (fig. 360), there are five pairs of co-openings, and

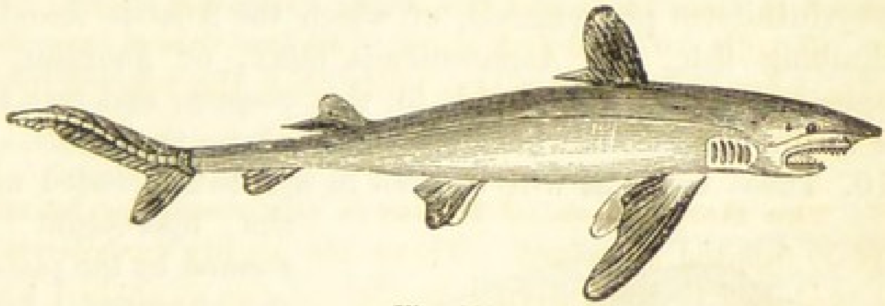


Fig. 360.
THE SHARK.

in the lamprey (fig. 361) seven. The internal arrangement

Fig. 361.
THE LAMPREY.

of the respiratory apparatus can therefore be always inferred by the mere inspection of its external openings.

With some species, the water does not pass directly from the mouth into the respiratory organ through the inter-branchial spaces, but arrives there by a canal, specially appropriated to that purpose, placed under the œsophagus, like the trachea in superior animals.

608. It will be evident, therefore, that fishes in general con-

sume much less air in respiration than animals which live in the free atmosphere. There are some species, however, which, not content with the air dissolved in the water, rise from time to time to the surface to inhale the free atmosphere. Some swallow it, taking it into the intestinal canal, where the oxygen is converted into carbonic acid. The loach presents an example of this curious phenomenon.

609. When fishes are moved from their proper element, they soon perish from asphyxia. This arises, not from the want of oxygen, but because the gills, no longer sustained by the water, collapse and become dry, and are incapable of fulfilling their functions. It is accordingly found that the fishes which perish most promptly in the air are those whose opercula are very widely cloven, so as to facilitate the evaporation upon the surface of the gills ; while those which resist such exposure longest, either have narrow opercula or some internal vessel in which water is preserved to moisten these organs. The family of Labyrinthiform pharyngeals, of which the Anabas scandens, or climbing fish, and Asphromenus olfax, or gourami, are examples, are very remarkable in this respect, and owe their name to the water-cells which are placed above their gills.

610. These cells, as will be seen in fig. 362 included under the operculum and formed by the plates of the pharyngeal bones, effectually serve the purpose of retaining a certain quantity of water, which keeps the gills moistened while the animal is in the air, and enables it to continue there for a considerable interval without any suspension of its vital functions. These species are accordingly accustomed to issue from the rivers and ponds which are their ordinary habitation, and, gliding over the ground, to depart to considerable distances on their banks. The anabas has this labyrinthine apparatus in its highest degree of perfection, and not only remains a considerable time out of the water, but is even said to climb up trees. These species inhabit chiefly India, China, and the Moluccas. One

Fig. 362.
THE ANABAS.

species, called gourami, of Chinese origin, much esteemed for its flavour, has been acclimated in the ponds of the Isle of France and Cayenne.

611. **The Respiration of Mollusca** is aërial or aquatic, and performed in some by pulmonary, and in others by branchial organs. These organs are consequently subject to much variation in form and position.

612. **In Cephalopods** the respiration is aquatic. The branchiæ are symmetrical, and consist of leaves of arborescent form, much divided and subdivided, concealed by the mouth in a cavity having contractile sides. When it is dilated, water enters, and is expelled by its contraction. A cleft is provided for the entrance of the water, and a tunnel-formed tube for its exit.

613. **In Gasteropods**—those which have shells and have aërial respiration—it is performed by means of a cavity, over the walls of which the pulmonary artery is ramified. This organ is generally placed in the last convolution of the shell. The air is admitted to the pulmonary cavity either by a small orifice left for the purpose in the shell, or by a canal placed between the body of the animal and the shell.

Shelled gasteropods with aquatic respiration have branchiæ. Sometimes the animal is obliged to protrude itself from the shell to put its branchial organ in contact with the water. Sometimes the respiratory organ is provided with a sort of canal or siphon, by means of which it can be washed, the animal remaining in the shell. Nerines, volutes (fig. 221), cerites, porcelaines, whelks, are examples of these.

Tecti-branchiate gasteropods have branchiæ half concealed by the mantle. The nudi-branchiates, which are destitute of shell, have the branchiæ on some part of the back.

614. **The Molluscous Acephala** are provided with four foliated and transversely striated branchiæ, placed between the mantle and the body of the animal.

615. **The Respiration of Insects** is less perfectly localised, but it is aërial, the circulation being very imperfect. The blood is not animated with a complete movement of revolution, and the air is conducted to meet it in its course at the same time in several parts of the system. The respiratory organ consists of a multitude of small tracheæ, which communicate with the exterior of the body by openings called *stigmata*. The tracheæ are sometimes merely ramified, but sometimes they have, from point to point, enlargements which form air sacs. They are kept open by a cartilaginous

coating of spiroidal structure. The stigmata resemble little clefts or button-holes, which are sometimes furnished with small valves. There is generally one pair of stigmata for each ring of the body. The renewal of the air in the tracheæ is produced by the alternate expansion and contraction of the abdomen. Respiration in winged insects is somewhat active, and, as a consequence, their temperature is sometimes elevated in a remarkable degree.

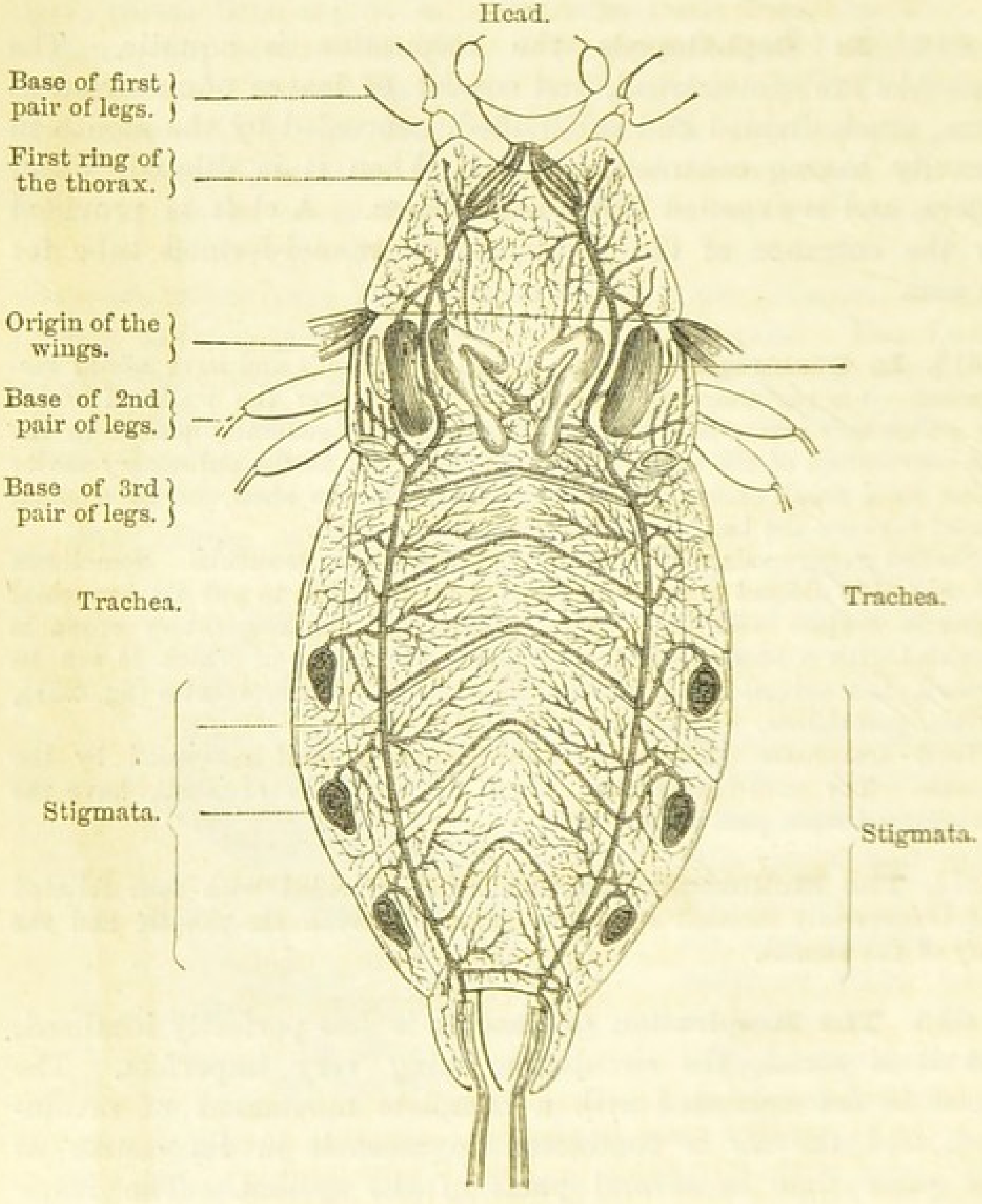


Fig. 363.

THE NEPA OR WATER SCORPION.

616. **Anatomy of the Nepa.**—The respiratory apparatus of insects may be illustrated by a reference to the general structure of the nepa, including that apparatus shown in fig. 363.

617. **The Respiration of Arachnida,** like that of insects, is aërial, and performed sometimes by the tracheæ and sometimes by air sacs placed in the abdomen, which as much resemble branchiæ as lungs. They present in their interior a multitude of lamellæ, resembling the foliated structure of gills. They receive air, like the tracheæ, by means of stigmata placed along the sides, or upon the lower surface of the abdomen.

618. **The Respiration of Annelidæ** is generally aquatic, the branchiæ being subject to much variation both in form and position. Sometimes—as, for example, in the arenicola or sand-worm, fig. 364—they form tufts placed at equal distances along the body. Sometimes, as in the nereids, fig. 208, they are grouped round the foot in the form of tubercles, and sometimes they are placed at the extremity of the body in a feather-like form, of which serpulæ, fig. 210, present an example. The only annelids which have not aquatic respiration are the common earth-worms, which live in the humid soil, and have cutaneous respiration, combined, perhaps, with respiration by small air sacs placed in the anterior part of the body, and communicating with the external air by pores.

619. **The Respiration of Crustacea** is in general aquatic and performed by branchiæ. Some of this class, however, having no branchiæ, respire by parts of the body covered by a soft integument. Some crustacea which live in the air respire by means of a multitude of external lamellæ kept in a state of permanent humidity, which form branchiæ and perform the office of lungs.

620. **The Respiration of Zoophytes** in general is performed without special organs, the interchange of gases with the atmosphere being made by the tegumentary covering of the body, as well external as internal.

In the case of some—as, for example, the holothuria, fig. 229, a special ramified canal is provided, somewhat analogous to a trachea, into which the water is introduced by a cloaca, and expelled from time to time by the contraction of the sides of the canal. In the case of *infusoria*, *vibratile cilia* are observed upon the surface of the body, by the movement of which the water of respiration is renewed.

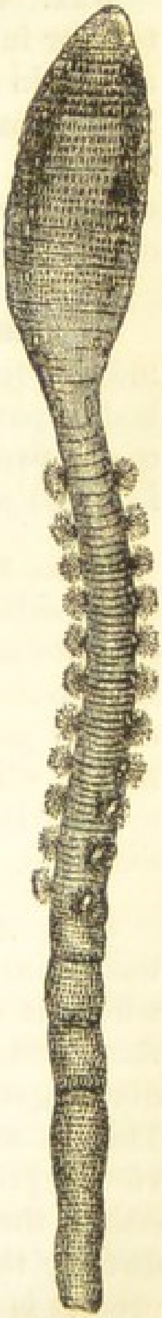


Fig. 364.
ARENICOLA OR SAND-WORM.

CHAPTER IX.

DIGESTION.

621. **Waste of the Body.**—Every motion, whether voluntary or involuntary, of the body or its organs, is attended with a certain wear of its structure. The parts worn out are dismissed just as are those of a piece of mechanism abraded by friction. This constant wear would at length produce decay and dissolution, if means were not furnished by which the organised matter lost could be restored.

622. **Repair by Nutrition.**—Nature has therefore provided means by which the animal, taking from external organised bodies parts of their substances, appropriates them to the repair of its own body. The function by which this is accomplished is called *nutrition*.

623. **Digestion.**—The matter thus received not being in a state suited for nutrition, and containing, moreover, certain constituents which cannot be at all adapted to that purpose, it is submitted in the organism to certain operations by which certain parts are modified so as to render them fit for incorporation with the system, and the residuum incapable of such modification is separated and expelled. This process is called *digestion*.

624. **Absorption.**—When the part fitted to replace the waste has been thus prepared, means must be provided by which it can be transported into and duly incorporated with the blood, which, as has been already explained, is the immediate agent by which the body and its organs are nourished. This is accomplished by the transmission of the matter previously prepared by digestion into the torrent of the circulation, either through the intervention of the lymphatics, or more directly through the coats of the veins and other vessels. This process is called *absorption*.

625. **Alimentary Canal.**—Vegetables receive nutriment into

their tissues directly from the earth by their roots, and from the air by their foliage. The nutrition of animals is more complicated, the matter from which it is derived not being so immediately suited for absorption. They are accordingly furnished with an internal apparatus, consisting of a cavity in which the matter taken from external organised bodies is elaborated, the nutritious parts being absorbed, and the unnutritious residuum expelled. In man and the superior animals this digestive cavity has the form of a tube open at both ends, of considerable length and variable diameter. It is called the *alimentary canal.*

626. **The Phenomena of Digestion** are therefore mechanical, chemical, and physiological.

The mechanical phenomena consist in the prehension of the aliments, their mastication, deglutition, propulsion through the alimentary canal, and in the expulsion of their undigested residuum.

The chemical phenomena consist in the decomposition of the aliment, the separation of its nutritious from its unnutritious constituents, and the solution of the former by, and their combination with, the several juices secreted in the digestive canal, so as to form a fluid suitable to nutrition.

The physical phenomena consist in the transmission of this fluid, through the coats of the vascular system, into the blood by absorption.

627. **Appetite and Hunger.**—The Author of nature, in his infinite beneficence, has appointed pain as a notice of approaching injury or bodily derangement. In proportion as the injury becomes nearer and more grave, the warning becomes more urgent. Nothing can be more admirable than the degrees by which this internal notice is regulated. The want of food in due time is attended at its first approach, not with positive pain, but with a desire, or *appetite*, as it is called, which holds an intermediate place between pleasure and pain—the pleasure consisting in the anticipation of gratification, and the pain in a slight degree of uneasiness attending the momentary postponement of this satisfaction. If the supply of food, however, be postponed so long as to produce the commencement of injury, uneasiness ensues, which increasing, becomes painful, and receives the name of *hunger.*

628. The commencement of appetite coincides with the

completion of the digestion of the food previously taken into the system. Its periodic returns vary with age, hygienic condition, and bodily habit. It may be stated however, generally, that the desire for food will recur with a frequency and intensity proportional to the activity and rapidity of digestion. Thus children are sensible of hunger more frequently than adults, convalescents more so than those who enjoy uninterrupted health. This is easily explained. Children and convalescents require food not only to replace the normal loss sustained by their organs, but to supply the means of increasing the quantity of matter in their system—the one because they grow, and the other because they require to regain that which was previously lost in the abnormal condition produced by disease. Exercise and labour also develop the sense of hunger, while sedentary habits have a contrary effect ; because the one stimulates digestion, while the other retards it.

629. Hunger, which is renewed in man two or three times a-day, is more imperious in animals of more active circulation and higher temperature. Thus, birds cannot survive a fast of twenty-four hours. Those animals, on the contrary, whose circulation is less active and temperature lower, feel it less frequently. Thus, hibernating animals, and some reptiles, can sometimes remain months without nourishment. It is said that the leech requires a year to digest the blood with which it is gorged.

630. The temperature of the medium in which an animal lives has a marked influence upon appetite. A low temperature stimulates hunger, while an elevated one renders it languid. In cold climates man struggles against the external cold by taking aliments in quantity and quality adapted to increase those internal combustions which are the source of animal heat.

631. Though the want of food be not so immediately destructive of life as the want of air, its ultimate effects are not less so. Animals deprived of it suffer a gradual decrease of weight and strength, and if the want be continued, death supervenes, after sufferings more or less prolonged.

632. **Thirst.**—Every cause which diminishes the due proportion of the aqueous constituent of the economy awakens the sense of thirst. An elevated temperature, by stimulating cutaneous and pulmonary evaporation, and violent exercise, which

increases the secretion of sweat, have this effect. Thirst is also excited in a morbid degree by that class of maladies which are attended by an undue secretion of urine, or by abundant hæmorrhage.

The sense of extreme thirst is even more intolerable than that of hunger. Shipwrecked persons suffer more from privation of drink than from privation of food ; and death from the former cause is more rapid than from the latter. Salt aliments produce thirst, because their saline constituents require a superabundant supply of liquid juices for their solution in the alimentary canal, and thus diminish the proportion of water in the blood.

Substances which irritate the stomach, such as pepper and spice, have a like effect. Since the sensation of thirst arises from an undue diminution of the aqueous constituent of the blood, any expedient which will restore the aqueous element, even though it do not act through the stomach, will diminish or remove the sensation. Thus, shipwrecked persons deprived of drink are enabled to slake their thirst to a certain degree, and prolong their lives, by immersion from time to time in the sea, retaining round their bodies the sea water with which their vestments are saturated. The water with which they are thus surrounded is decomposed by evaporation, the salt being dismissed, and a portion of the pure fresh water entering the blood through the pores of the skin.

633. **Aliment—its Constituents.**—Since the food taken into the system supplies the sole materials out of which the body is formed and maintained, it must necessarily contain all the constituents of the body in a due proportion. The food used by man is exclusively animal or vegetable ; but the meat, vegetables and fruits which we eat, the water, wine, and the liquors which we drink, include, besides their proper organic principles, certain others, such as salt, lime, sulphur, phosphorus, iron, and other mineral substances. These mineral constituents, like the organic matter properly so called, are appropriated to the renewal of the solid and liquid parts of the organism ; for the tissues contain all these several mineral constituents. Among the substances thus derived from the mineral kingdom, salt plays the most important part in the functions of digestion, by favouring the secretion of the juices, exciting the sense of thirst, and the introduction of liquid, which aids the process of absorption. All the superior animals as well as man have

therefore a marked appetite for this mineral, and eat it with avidity.

634. **Mineral Substances alone cannot support Life.**—Although mineral substances thus play an important part in the phenomena of digestion, they are incapable of themselves to support life. Nomadic and savage tribes, to appease the sense of hunger, sometimes introduce into the stomach certain aromatic earths, but never derive nutrition from them, except when they contain some organic principles. If organic substances, on the contrary, are found to be sufficient for the maintenance of life, it is because independently of their organic constituents, properly so called, they also include the mineral matter necessary for the supply of the tissues.

635. **Animals denominated Herbivorous, Carnivorous, and Omnivorous.**—Although all the constituents of food, such as charcoal, lime, salts, and gases, are found in the material world in their simple state in unlimited quantities, the animal organs are not so constituted as to appropriate them immediately, and to convert them by mere digestion into a state suitable for their maintenance. These simple alimentary principles must undergo a previous process, by which they are transmuted from the unorganised to the organised state before they are fitted for animal nutriment. This change is effected chiefly in the vegetable kingdom, where such substances are converted into those forms of organised matter which constitute vegetable food. This forms the exclusive aliment of a certain class of animals, which are thence denominated *herbivorous.*

Other animals are provided with a digestive apparatus which is not capable of converting such forms of food into the organised matter of their bodies, and these feed upon the bodies of other animals which are destined by nature to become their prey. Such are accordingly denominated *carnivorous.*

In fine, there are other classes, among which man is included, whose digestive apparatus is adapted to both kinds of aliments, and these are accordingly denominated *omnivorous.*

636. **Nitrogenised and Non-Nitrogenised Aliments.**—Notwithstanding the infinite variety of form and quality of which food is susceptible, it may be reduced to two classes, having an

important relation to the digestive functions ; one of which is characterised by the presence, and the other by the absence, of azote or nitrogen as a constituent. The one class is accordingly denominated *nitrogenised*, and the other *non-nitrogenised* aliments.

All nitrogenised aliments include a quarternary compound, consisting of carbon, hydrogen, oxygen, and azote ; and all non-nitrogenised aliments include a ternary compound, consisting of carbon, hydrogen, and oxygen, with the exclusion of azote. Both of these combinations enter into the composition of all food, animal and vegetable, but the nitrogenised character has a marked predominance in the former, and the non-nitrogenised in the latter.

637. The combination of these two principles in due proportion is indispensable to the nutritious character of all aliments. Each of the two principles is endowed with its peculiar physiological property. The nitrogenised part goes to the formation and repair of the tissues, and the non-nitrogenised to the production of that animal heat which is necessary to the maintenance of the temperature of the organism.

Nitrogenised food has therefore been sometimes denominated *plastic*, and non-nitrogenised, *respiratory* or *calorifacient*.

Examples of nitrogenised aliments are presented in food of animal origin; by the lean of meat, and, in general, the muscular parts of all flesh, the white of eggs, milk, and cheese, and the gelatinous principle extracted in soup from various parts of the animal, such as the tendons, ligaments, membranes, skin, and bones.

Similar examples are presented in the case of vegetable food by the gluten, which forms the nutritive principle of most kinds of grain, and many seeds ; the albumen of all vegetable juices, and the caseine which constitutes the nutritious principle of peas, beans, lentils, and the like.

Examples of non-nitrogenised aliments are presented in the case of food of animal origin, by fat, butter, milk, and honey ; and in food of vegetable origin, by starch, sugar, gum, mucilage, and the gelatinous principle of fruits and oils.

638. The imperious necessity for nitrogenised constituents in food is demonstrated by the fact that nitrogen constitutes an important part of the animal tissues ; and since, in the phenomena of digestion, no elementary substances can be evolved except such as are already contained in the food, it follows that the presence of nitrogen as a constituent of food is indispensable. Plants, it is true, take an important part of their nourishment from the atmosphere ; but man, instead of borrowing from the atmosphere, gives to it, in respiration, a large quantity of carbon, and at least as much azote as he receives from it.

639. Since nitrogenised and non-nitrogenised matters enter into the composition of animal as well as vegetable food, it follows that man can subsist on the one or the other; but, since there is a deficiency of the nitrogenised principle in the one, and of the non-nitrogenised in the other, either regimen adopted exclusively will be inferior in its nutritive power to one in which both are duly mixed.

Haller ascertained, by numerous and well-conducted experiments, that an exclusively vegetable regimen was productive of a diminished development of the tissues, and enfeebled muscular power.

The operatives employed in the iron works of Tarn, in France, had for a long time subsisted on a regimen exclusively vegetable. It was observed that during this period each of them was disabled by fatigue or indisposition an average number of fifteen days per annum. In 1833, M. Talabot, taking the direction of the works, changed the regimen, adopting the ordinary one of animal and vegetable food. The health of the men was so increased, that after this the number of days per annum lost by indisposition was reduced to three. The mixed regimen therefore gave twelve days per head per annum of greater capability of labour.

640. The difference between animal and vegetable food is one therefore of proportion only, and not of kind, both containing the nitrogenised and non-nitrogenised constituents, though in different proportions. It is for this reason that animals entirely carnivorous can be nourished artificially on vegetable food, and those entirely herbivorous on animal food. The pig, which lives entirely on roots, can live upon meat, and the dog, naturally carnivorous, on bread.

The proportion of nitrogenised constituents contained in vegetables being comparatively inconsiderable, herbivorous animals supply the deficiency of nitrogenised matter by the increased quantity of food consumed.

A horse or an ox consumes per day the tenth or twelfth of their weight in vegetable food, while the dog or cat are able to subsist upon the thirtieth of their weight in animal food. It is for this reason that the digestive canal of herbivorous is formed with greater capacity than that of carnivorous animals.

641. In the human organism there are many indications of the omnivorous character. The dentary mechanism includes the incisors and canines of the carnivorous, and the molars of the herbivorous animals. The capacity of the digestive canal exceeds that of the carnivorous, while it falls short of that of the herbivorous animals.

Experiments prove that the exclusive use either of nitrogenised or non-nitrogenised food is incompatible with the continuance of life. Thus, dogs fed with sugar, olive oil, gum, or butter, by M. Magendie, lost weight, and

lived only thirty days. Geese fed upon sugar, gum, or starch, by Messrs. Tiedemann and Gmelin, lost weight and died from the sixteenth to the twenty-seventh day.

Like results followed from the exclusive use of nitrogenised food. A goose fed by Messrs. Tiedemann and Gmelin upon the white of egg, boiled and hashed, died upon the forty-sixth day.

Dogs fed exclusively upon fibrine, albumen, and gelatine, either separately or together, survived for three months only.

642. When the aliment on which the animal subsists exclusively contains nitrogenised and non-nitrogenised constituents in suitable proportions, life and health can be sustained by it. Thus, milk given exclusively can support life; bones will nourish dogs. Rice alone has also supported animal life, because it contains a considerable proportion of nitrogenised constituents. Peas, lentils, and beans, which contain the same proportion of nitrogen, have probably a corresponding nutritious effect.

643. Independently of the peculiar composition of each kind of aliment, variety is found to be indispensable to the health of the animal. Thus, if we take an animal which feeds indifferently upon various sorts of vegetables—a rabbit for example, which eats several kinds of grain and vegetables, such as cabbage and carrots—it will fatten, if supplied with these several sorts of food together or in succession ; but if it be limited to any one of them it will exhibit all the external signs of starvation, and in two or three weeks will die in the same manner as it would of total want of food.

644. Man rarely consumes aliments, whether animal or vegetable, in the state in which nature supplies them. They are generally submitted to a previous culinary preparation, by which their digestion is rendered more easy. This consists in combining together different alimentary substances so as to transform incomplete and imperfect into more perfect food.

It is thus that vegetables which contain but little azote are mixed with the gravy of meat and milk, which impart to them more nutritive properties. The different condiments which are taken with food, such as pepper, salt, mustard, and the exciting liquids which are used with these seasonings, such as lemon, vinegar, &c., act upon the stomach in a manner to favour secretion of the gastric juice, or more directly to cooperate with that principle.

645. **Prehension of Food.**—Nature has provided all animals with instruments variously adapted to the seizure of the food and its conveyance into the alimentary canal. In man, the superior members, composed of the hands and arms, accomplish this. The joints of the arm are so disposed as to direct the

hand to the mouth with the greatest promptitude and facility; and the articulation of the head with the trunk facilitates at the same time its inclination to meet the hand.

646. When the aliment has a volume disproportionate to the magnitude of the buccal cavity, into which it must be introduced, we divide it either by means of the hand, or by the intervention of mechanical instruments. Sometimes the teeth are used for this purpose, one part of the food to be divided being seized by the incisors, while another is drawn from the mouth by the hands. Man also, like the inferior animals, can seize his food directly with the mouth, without the intervention of the hand, but the prominence of his nose and chin render this operation much more difficult than in the case of animals, in which the mouth, by its form and position, is more expressly adapted for prehension. Man, therefore, never uses the mouth for prehension, save in the exceptional cases where he is deprived of the use of his hands and arms.

647. **Prehension of Liquids.**—Liquid nourishment is generally drawn into the alimentary canal by the process of suction, which is the first nutritive act of the infant on coming into the world. The action of the infant mouth in drawing milk from the maternal pap is a curious physical experiment. The lips are applied to the breast round the pap so as to be in air-tight contact with it; at the same time the tongue, which previously fills the mouth, is withdrawn, the veil of the palate being closed so as to render the interior of the mouth a partial vacuum. The atmospheric pressure then taking effect upon that part of the flesh of the breast which is outside the infant's lips, acts upon it so as to press the milk through the opening of the teat into the mouth. When the mouth is thus filled the veil is opened and deglutition takes place, the milk descending through the upper part of the alimentary canal into the stomach. The veil of the palate is then again closed, and the same operation repeated.

In this case the mouth acts like a common India-rubber syringe, the sides of which, being first pressed together, exclude the air; and when allowed to expand, the liquid in which the syringe is immersed is forced in by the atmospheric pressure acting upon its external surface. The tongue also plays the part of the piston of a common syringe, first filling the mouth so as to exclude the air, and then, by being withdrawn, leaving above it a partial vacuum, so as to give effect to the external pressure of the atmosphere. When a man drinks from a cup

or glass the operation is performed upon the same principle ; the under lip being applied to the exterior part of the edge of the cup in air-tight contact with it, and the upper lip being at the same time immersed in the liquid, a partial vacuum is produced within the mouth in the manner explained above, and the atmospheric pressure acting upon the surface of the liquid in the cup forces it into the mouth.

In some cases the liquid is drawn into the mouth without the direct intervention of atmospheric pressure. Thus, when we take soup from a spoon, without placing the upper lip in contact with it, a current of air is drawn into the mouth between the lip and the liquid. This current, acting upon the surface of the liquid, has a tendency, as it were, to blow it into the mouth. In such a case, however, the movement of the liquid is chiefly produced by its gravity, the outer part of the spoon being a little lifted, so that the liquid falls, as it were, into the mouth.

648. **Mastication.**—The adaptation of the jaws and teeth to the division and trituration of food has been so fully described in a former chapter, that little need be said of it here. The subdivision of the food by mastication is essential to its easy digestion, by exposing a larger surface of it to the action of the juices secreted in the alimentary canal. This has been proved directly by experiments on artificial digestion, in which food more or less broken up and triturated has been exposed to the action of these juices. It is, however, more especially with vegetable food that mastication is indispensable. The nutritive parts of vegetable food generally are included in envelopes or husks, which would resist the digestive juices. These envelopes must therefore be broken by the teeth, to extract the alimentary matter. Animals which live on vegetable diet, such as grain and forage, masticate their food much more perfectly than do carnivorous animals, whose masticating apparatus is adapted rather to seize and tear their prey than to triturate it. Aged horses, whose teeth are worn, often perish by reason of the indigestibility of their nourishment, when care is not taken to have it chopped and bruised.

649. The process of cooking, to which vegetable food for man is subjected, contributes to render mastication more easy by softening and even bursting the envelopes which include the nutritive matter. But even then mastication is still necessary. When it is not effected, vegetable food, such as peas, beans,

and lentils, often passes through the system, and is rejected unchanged in the fæces. How much the efficacy of the digestive functions depend on due mastication is well understood by those who suffer from imperfect digestion.

650. **Alimentary Canal.**—Complicated as is the series of physical and physiological processes which are carried on in the digestive apparatus, it is surprising by what simple means nature has attained her purpose. To render the form and structure of the alimentary canal more easily intelligible, we shall first consider it to be extended into a straight line, postponing for the moment the explanation of the manner in which its vast length is packed into the apparently small capacity of the abdominal cavity.

Supposing then the entire digestive canal to be extended in one continuous straight line, commencing at the mouth, where the food is introduced, and terminating at the anus, where its undigested residuum is expelled, the whole apparatus thus arranged for illustration is represented in Fig. 365, the several parts of which it consists, and appendages annexed to it, being marked upon it.

Its total length in the human economy, from the mouth to the lower extremity, is about thirty feet. It is a flexible membranous tube of small calibre. In the figure, the several parts of its length are represented nearly in the proper proportion upon the scale of an inch to two feet. The diameter, however, of the different parts is necessarily on a larger scale. To bring the figure conveniently within the page, the entire length is divided into two equal parts, the top of that which is at the right of the page being the continuation of the bottom of that which is at the left. It will be observed that the tube is not of uniform diameter, but has several enlargements, as well as appendages passing into it by lateral tubes. The first enlargement of its summit is the mouth, separated from the second, called the *pharynx*, by a contracted aperture furnished with a valve opening backwards and downwards, through which the food passes. The pharynx is succeeded by a portion of the tube about nine inches in length, and less than one inch in internal diameter, called the *œsophagus*, which terminates in another enlargement of this cavity, which, when completely filled, contains from three to four pints. This membranous bag is the *stomach*.

From the stomach the canal is continued by a narrow flexible tube about twenty feet long, called the *small intestine*. This tube is divided by anatomists into three parts of unequal length,—the first issuing from the stomach, and having a length of about nine inches, and called the *duodenum*, from the circumstance of its estimated length being twelve finger breadths. The diameter of this part varies from an inch-and-a-half to an inch and three-quarters. This is followed by the *jejunum*, measuring about eight feet, and having a diameter which varies from an inch to an inch-and-a-half. This part of the tube derives its name from the fact of

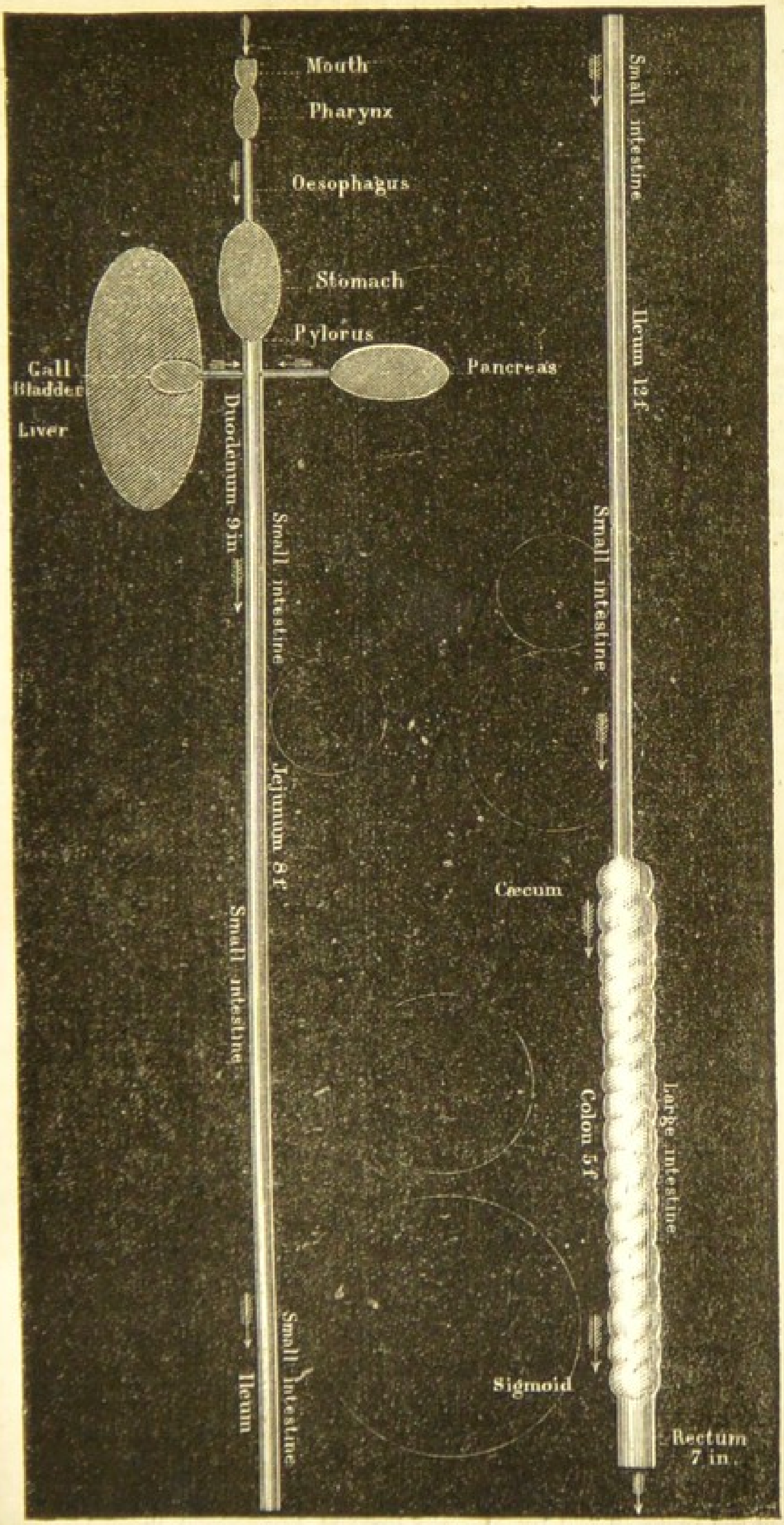


Fig. 365.

THEORETICAL DIAGRAM OF THE ALIMENTARY CANAL IN THE HUMAN ORGANISM.

its being found generally empty after death. The last and largest division of the tube, measuring about twelve feet in length, and having a diameter varying from an inch to an inch-and-a-quarter, is called the *ileum*,—a Latin word signifying a small gut.

The ileum is succeeded by part of the digestive canal, measuring five feet in length, and about two inches and a half in diameter, called the *large intestine*, the structure of which is altogether different from that of the small intestine. As shown in the figure, it consists of a series of annular contractions, and having a muscular structure, it has the property of pushing onwards the residuum of the food which passes through it towards the extremity, where this annular structure ceases, the tube becoming again cylindrical.

The terminal part of the alimentary tube which has this cylindrical form, or nearly so, is called the *rectum*, and is about seven inches in length, having a diameter somewhat less than that of the sigmoid flexure which enters it ; but it becomes dilated into a large ampulla, or reservoir, for the reception and accumulation of the fæces immediately above the anus. This terminal enlargement is not represented in the figure.

The extremity of the large intestine into which the ileum enters is called the *cæcum*, from being a blind pouch, or cul de sac, and the other extremity, which opens into the rectum, is called, from a circumstance which will presently be explained, the *sigmoid flexure*—the intermediate part of the great intestine being called the *colon*.

The opening from the stomach into the duodenum, called the *pylorus*,

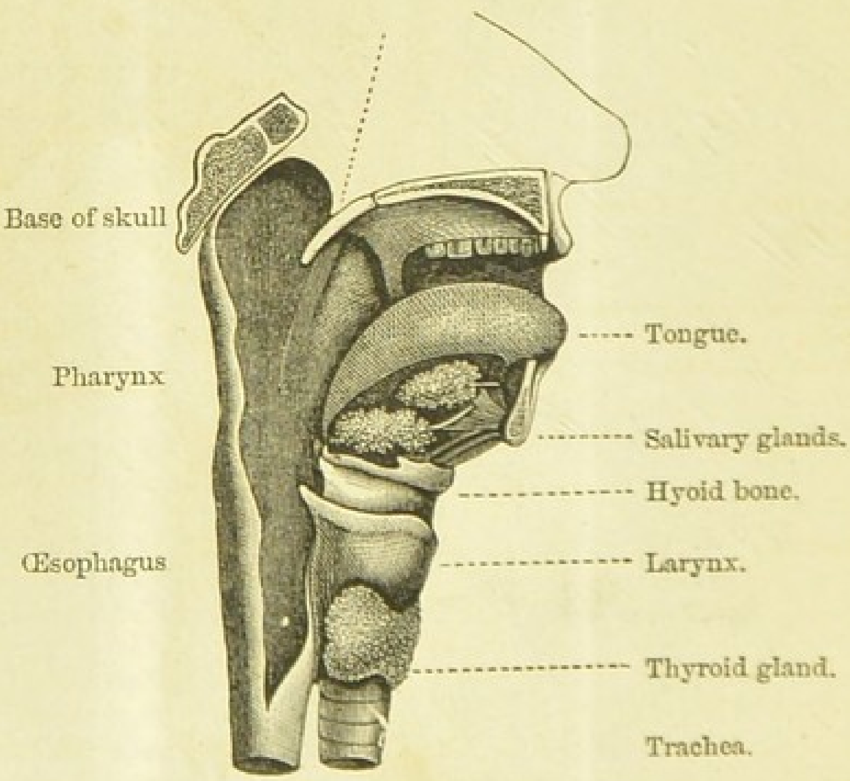


Fig. 366.
PHARYNX AND ŒSOPHAGUS. (Edwards.)

is surrounded by a strong muscle, capable of closing and opening, so as to perform the function of a valve. The piece of mechanism takes its name

from a Greek compound—πύλη (pulé), a door, and οὖρος (ouros), a guard. A valve, called the *ileo-cæcal valve*, is also interposed between the ileum and the cæcum.

2 Lower end of œsophagus.
1 Stomach.
3 Left end of stomach.
4 Right end of stomach.
5, 6 Duodenum.

7 Convolutions of jejunum.
11, 12, and 13 Ascending, transverse, and descending colon.

8 Convolutions of ileum.
9 Cæcum.

10 Its vermiform appendix.
14 Sigmoid flexure.

15 Rectum.

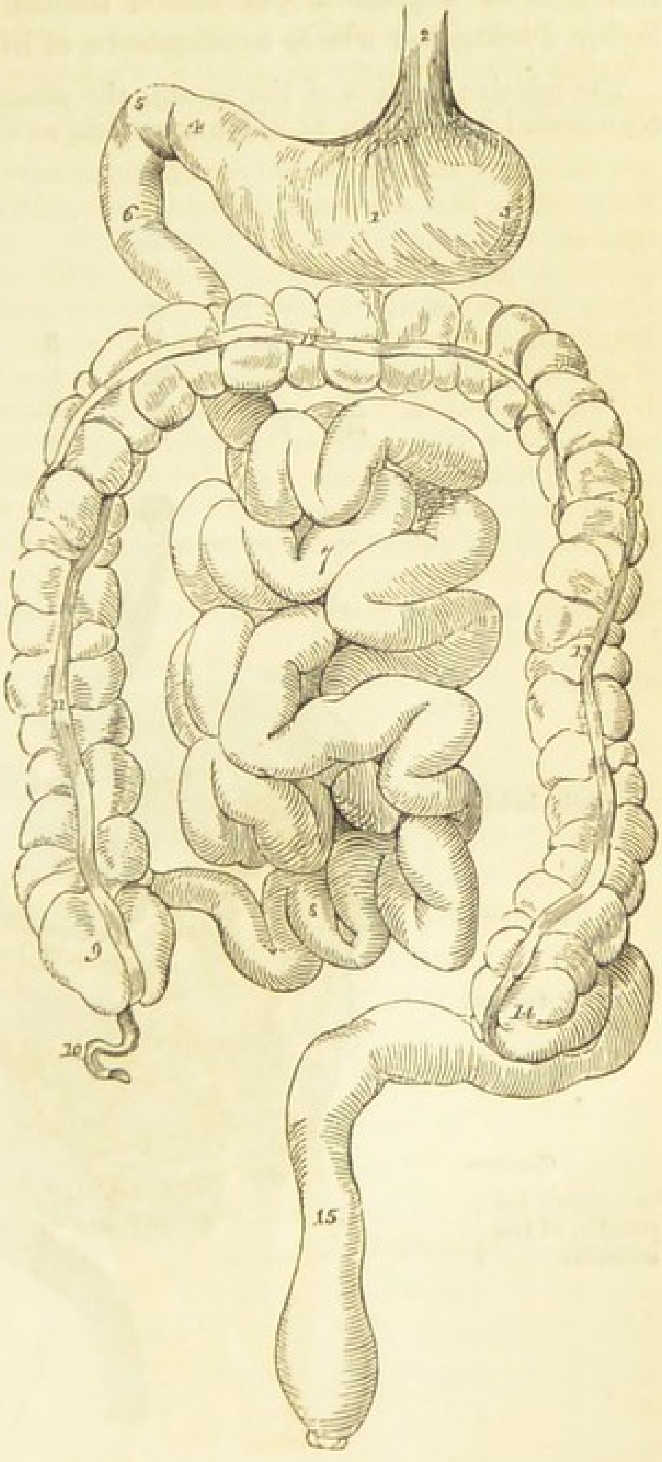


Fig. 367.

The ducts of the liver and gall-bladder, and of the pancreas,—organs which will be described hereafter—open into the duodenum a little below the pylorus.

651. Let us now consider how the comparatively enormous length of this apparatus is not only packed within the limited capacity of the abdomen, but so arranged there that the function of digestion performed within it proceeds with regularity during the whole continuance of life.

The relative position of the mouth, the pharynx, and the œsophagus, is represented in fig. 366, in which a vertical section of these parts is shown.

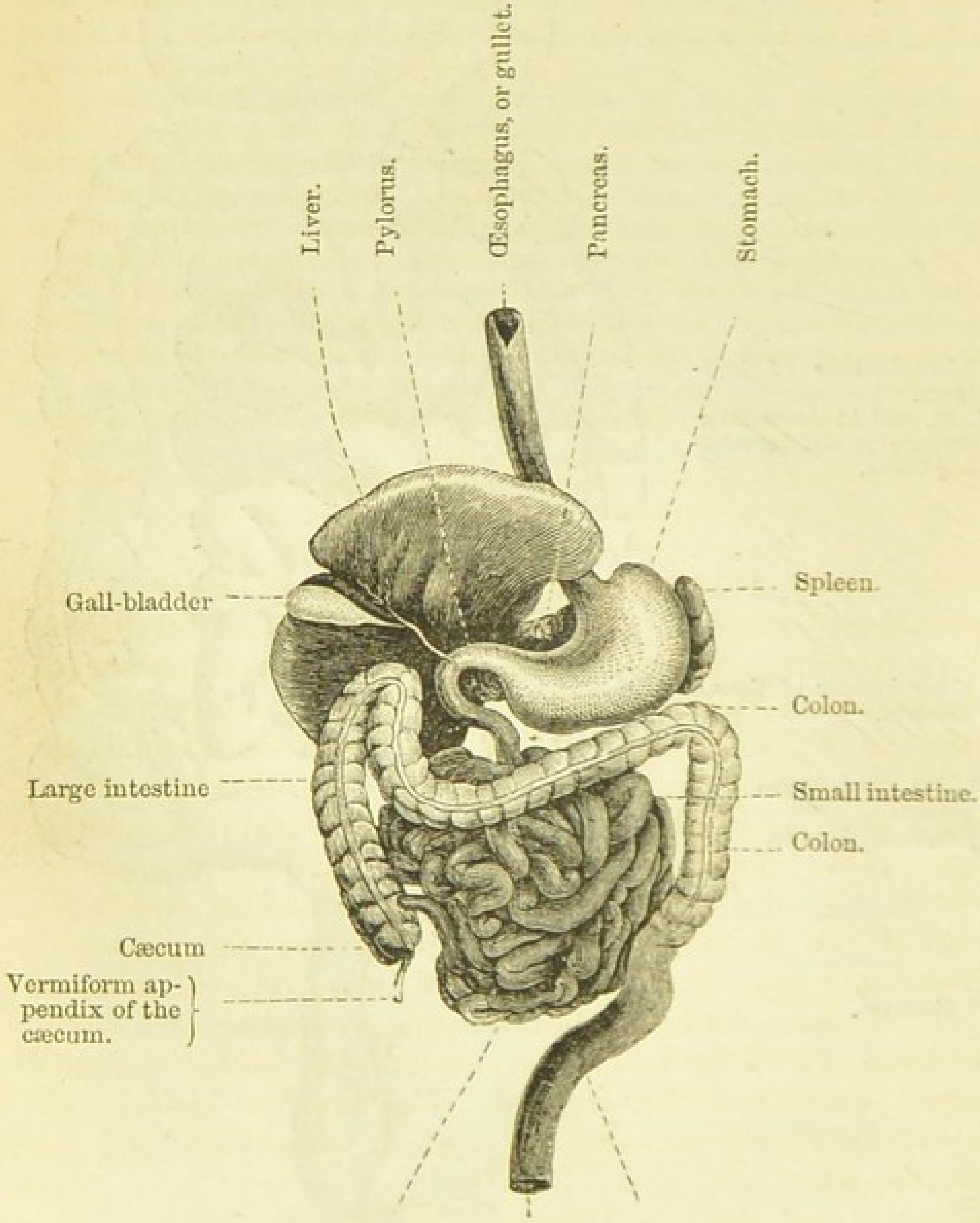


Fig. 368.
ALIMENTARY CANAL. (Edwards.)

The œsophagus, which takes its name from a Greek compound signifying

food-bearer, is a membranous tube which passes down the neck behind the windpipe, between the two carotid arteries, and descending through the thorax, passes through the diaphragm, and enters the upper part of the stomach.

The stomach, and all the inferior part of the alimentary canal, are represented as naturally arranged within the abdomen in fig. 367.

It will be seen that the stomach is an oblong bag placed horizontally, the œsophagus (2) entering at the uppermost portion, and a little on the left of the middle of the cavity.

The duodenum (5, 6) leads from the right side of the stomach, and bending downwards, descends to the jejunum, the convolutions of which occupy the upper part of the abdominal cavity. Below these are the convolutions of the ileum, the lower extremity of which enters the large intestine laterally,—that small portion of the great intestine (9) below the point of junction with the ileum, being called the cæcum. The great intestine rises so as to form a sort of arch, the upper part of which is nearly in contact with the lower part of the stomach. From the form in which it is arranged in the abdomen, the *colon* is distinguished into three parts, called the *ascending*, *transverse*, and *descending* parts. The *sigmoid flexure* (14) takes its name from the peculiar form into which the intestinal canal is there bent, bearing a resemblance to the Greek letter Σ.

The terminal ampulla of the rectum (15) already mentioned, is shown in the figure.

The liver and pancreas, which are not represented in fig. 367, are included in fig. 368, the several parts being indicated as before.

652. **Coats of Alimentary Canal.**—The alimentary canal, from the pharynx to its lowest extremity, is lined throughout with a covering called the *mucous membrane*, which, although a continuation of the skin, differs from it by the absence of the epidermis, which is replaced by a soft cuticular tissue, called the *epithelium*, thickly overspread with a network of minute blood-vessels and lymphatics, and containing innumerable secreting pores. This membrane is sheathed in another of *muscular structure*, by the contractions and relaxations of which the contents can be moved in the canal during the process of digestion, or arrested at certain points during intervals more or less continued. In fine, a third coating, consisting of a serous membrane, called the *peritoneum*, encloses the whole. A fourth coating is also described, composed of cellular or areolar substance, interposed between the mucous membrane and the muscular coat.

653. **The Stomach.**—The stomach, into which the food, after mastication and insalivation, is transferred through the œsophagus, is a bag, lined by an extensive and loosely connected mucous membrane, which, when empty or only partially filled,

forms wrinkles and folds on its internal surface. These, however, disappear altogether when it is distended by food. The narrow opening at the lower extremity of the œsophagus, at which the food enters the stomach, is called the *cardiac orifice*. After the passage of the food this orifice is closed, so as to resist its return towards the mouth, which otherwise might take place by the action of the contractile force of the muscles surrounding the stomach. Sometimes, nevertheless, more or less of the food is forced upwards and thrown into the mouth, as in the case of eructation or vomiting; this happens, however, with more facility, and therefore with more frequency, in the case of gases evolved in the stomach.

654. **The Mechanical Action of the Stomach** forms an important part in the process of digestion. By this involuntary action the aliment is rolled about, so that every part of it is brought successively into contact with the mucous membrane which lines the stomach upon which the gastric juice is secreted. Every part of the food is thus successively impregnated with the gastric juice. The necessity of this stomachic action is illustrated by dividing the pneumo-gastric nerves (fig. 270, [12], 270, [13]), which excite this involuntary motion. After their section the motion ceases, and no parts of the food receive directly the gastric juice except those which lie on the outside of the mass and immediately in contact with the coats of the organ. The central parts consequently remain undigested.

This mechanical action of the membrane of the stomach has been demonstrated in various ways.

M. Reclam, having kept a dog fasting for a sufficient time to render the stomach empty, gave it an abundant meal of milk very rich in caseine, which consequently coagulated upon being received into the stomach. Having opened the animal, and removed the stomach, he showed the marks of its mechanical action upon the coagulated mass.

The same physiologist produced a series of artificial digestions by placing broken and triturated food in phials surrounded with gastric juice, and maintained at the temperature of the blood of the living animal. When the phials were kept at rest, the digestion of the food was only superficial, but when they were agitated it was perfect.

In the case of patients suffering under gastric fistula, rods of whalebone introduced through the fistula into the interior of the stomach were sensibly affected by the internal movements. These movements have been also felt directly by the finger introduced through the fistula of a dog and brought into immediate contact with the stomach.

655. The stomachic movements are not simultaneous, but successive, passing over the surface of the organ with a sort of

undulatory motion, the effect of which is obviously to transfer the food successively from one part of the stomachic cavity to another, and thus to mix it more effectually with the gastric juice. The character of these movements varies in different animals, according to the modes of digestion.

M. Schultze showed that in the case of herbivora it is a motion of revolution, while in that of carnivora it is an alternate motion from side to side. Dr. Beaumont observed it in a patient affected with gastric fistula, and found that it was similar to that which M. Schultze had ascertained it to be in the case of herbivora. The aliments made a complete revolution of the stomach in from one to three minutes. When the stomach is paralysed, as above explained, by the section of the pneumo-gastric nerves, it may be put in action by the irritation of the extremity the nerve which leads to it, in which case the efficacy of the digestive process is artificially restored.

656. **Eructation.**—When gases are evolved in the stomach they produce an uneasy, and often a painful sensation. They are sometimes expelled through the œsophagus by the mere contraction of the stomach, or by that contraction aided by the abdominal muscles and the diaphragm. By their specific levity they have always a tendency to accumulate in the most elevated part of the stomachic cavity; and therefore, when we stand or sit upright, they are collected immediately under the cardiac orifice, and their expulsion is rendered more easy than when the body is extended horizontally. When such gases are developed, as often happens, at night, their expulsion is facilitated by merely sitting upright in the bed, or still more effectually by rising from bed and walking about; the motion aiding their displacement. The disagreeable odour which sometimes attends these gases proceeds from the vapours of digestion slightly acidulated, with which they are mixed.

657. **The Mechanical Action of the Intestines** is not less important to digestion than that of the stomach. So long as the food in the stomach is imperfectly digested, the pylorus remains closed so as to prevent its passage into the intestines; but so soon as the stomachal digestion is completed, this exit is opened, and the food is driven through it into the intestine by the contractile force of the muscles of the stomach. The pylorus is closed and opened, not by a valve, but by a strong muscular apparatus called *sphincter*, which acts under the stimulus of the food and independently of the will.

In the duodenum the food is mixed with the bile and pancreatic juice, as will be hereafter more fully explained. It

passes thence successively into the jejunum and ileum. Its progress through the small intestine is determined by the peristaltic action of that organ, produced by two systems of muscular fibres in its coat, one longitudinal and the other circular. The gases, always developed in a greater or less quantity in the intestines by the process of digestion, facilitate this motion, as air does in the air-vessels of a force-pump.

The movements of the intestinal tube are called *peristaltic* or *vermicular*, and consist in the alternate contraction and dilatation of successive portions of the muscular coat in a wave-like manner. These movements are involuntary, and are excited by the presence of the food in process of digestion. The impression produced by the food, being unperceived and uninfluenced by the will, belongs to the class called by physiologists *reflex*

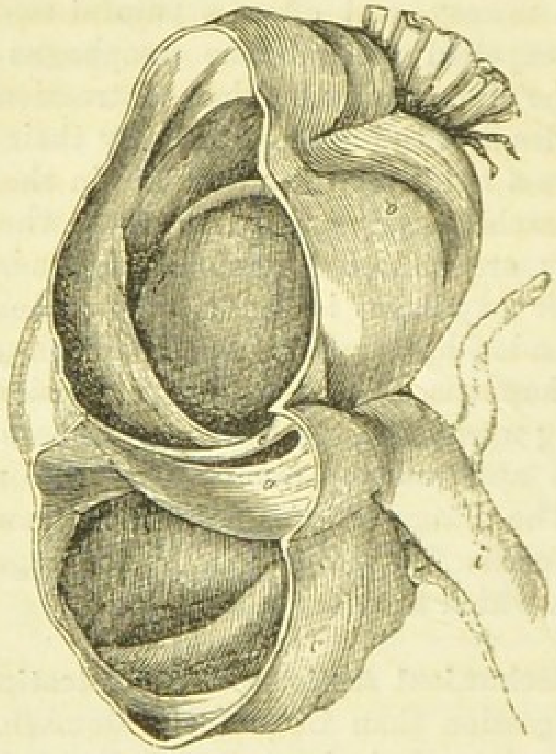


Fig. 369.

nervous actions. Nearly all the intestinal and stomachal motions are under the influence of the great sympathetic nerve. A mechanical, chemical, or galvanic excitation applied to the semilunar ganglions (fig. 270,[48]), the solar plexus (fig. 270,[50]), or the splanchnic nerves (fig. 270,[47], 270,[49]), produces the contractions proper to the small intestine. When the communication of the great sympathetic with the cerebro-spinal system is cut off, the intestinal functions are suspended. This explains

the sluggish action of the intestines and their occasional paralysis, in maladies of the spinal marrow or the encephalon.

658. **The Mechanical Action of the large Intestine** is analogous to that of the smaller.

All that part of the food which has not been absorbed before its arrival at the extremity of the small intestine, passes from the ileum through a valve called the *ileo-cæcal valve* into the first portion of the large intestine, called the *cæcum*. The ileum enters the cæcum laterally, as shown in fig. 367, a little above the extremity of the cæcum, which derives its name from being a *cul de sac*, or *blind gut*. The part of the great intestine thus called is shown at fig. 367,[9], and lies below the entrance of the ileum into the large intestine.

The junction of the ileum *i* with the large intestine is represented in fig. 369, the cæcum and colon being laid open to display the ileo-cæcal valve, of which *a* is the lower, and *e* the upper fold, *c* being the cæcum, and *o* the ascending colon. This figure is given by Quain, slightly modified from Santorini.

The structure of the valve is such that it opens towards the cæcum, the two leaves meeting each other when closed, so as completely to prevent the reflux of the matter into the ileum.

The residual matter driven successively through the ascending, transverse, and descending division of the colon (fig. 367, [11], [12], [13]), arrives at the sigmoid flexure. This matter arriving constantly, and in a small quantity, at the extremity of the alimentary canal, from which it is expelled only at intervals more or less distant, must be provided with a reservoir, where it can be collected between the epochs of its expulsion. The reservoir is an enlargement of the rectum, forming a sort of ampulla, which lies immediately above its termination, as shown in fig. 367.

The movements of the large intestine are rendered visible in the living animal by opening the abdomen. They are less pronounced than those of the small intestine, but have the same character. It is in the ascending colon (fig. 347, [11]) that they are most remarkable. Like the other peristaltic motion, they are under the influence of the great sympathetic. The first portions of the ascending colon are influenced by the solar plexus, fig. 270 [50]. The lower part of the rectum is influenced by the hypogastric plexus (fig. 270,[64]), which includes filaments from both the great sympathetic and cerebro-spinal systems. The movements of the large intestine, in all parts which receive only the filaments of the great sympathetic, are involuntary; but the lower part of the rectum has a certain sensibility connected with the want of defecation, and its closing muscle, which receives filaments of the cerebro-spinal system, has a certain sensibility, and is under the dominion of the will.

659. **The Chemical Phenomena of Digestion** have for their ultimate purpose the absorption of the nutritious parts of the food by the organism. The first effect is, therefore, the solution of the alimentary substances; and when the aliments are not immediately soluble, they are rendered so by the action

of the digestive juices. When they are soluble, on the other hand, the action of these juices is limited to their simple solution.

In this process drinks are powerful aids to the digestive juices. Water itself acts as a solvent on a great number of substances. Alcoholic, fermented, acidulous, and alkaline drinks, severally contribute to the solution of alimentary matters. These also often act chemically in a manner similar to the digestive juices themselves. The juices secreted in different parts of the alimentary canal have different effects upon the food, but the production of these effects are not always confined to the place where the juices are secreted. The aliment charged with the juices secreted at one point of the canal, progresses onward to other points before the chemical action due to the juices with which it is impregnated takes effect. The consequence of this is, much complication in the chemical effects of digestion. Secondary effects also intervene to increase this complication. Thus, a portion of aliment charged with a certain digestive juice, will react upon other portions not so charged, and produce complicated effects. The digestive juices are five: 1, *saliva;* 2, the *gastric juice;* 3, the *pancreatic juice;* 4, the *bile;* and 5, the *intestinal juice.*

660. **Insalivation.**—While the food introduced into the mouth is broken, triturated, and ground by the jaws and teeth between which it is continually thrown by the mechanical action of the tongue and cheeks, moved by suitable muscles, a liquid called saliva is poured into the mouth from surrounding glands, which moistens the food and reduces it to a pulp. This process constitutes an important part of digestion; for although the saliva, as will presently appear, consists of more than 99 per cent. of pure water, the constituents, small as they are in quantity, which it holds in solution, exercise a considerable influence upon the preparation of the aliment for absorption and assimilation. Thus, insalivation not only facilitates the deglutition of the food by reducing it to a moist and soft pulp, which is easily moved through the œsophagus, but prepares it for the chemical changes which it must undergo in the stomach.

661. **The Mastication** of the food is not only necessary for its due impregnation with saliva, but also to its exposure in

the alimentary canal to the chemical action of that and other juices, the effect of which in a given time upon a given weight of food will be proportional to the extent of surface in contact with them. If the food be swallowed after imperfect mastication, and therefore in lumps of greater or less magnitude, the juices, acting only on the surface of each lump without penetrating to the inside of it, will necessarily produce imperfect effects, and the inconvenience and injury attending indigestion must ensue. These circumstances, being well understood, will impress on everyone the importance of perfect mastication, as a condition indispensable to the maintenance of health.

662. **Secretion of Saliva.**—Among the many admirable and beneficent provisions of nature, there is one attending the secretion of saliva which ought not to be passed without a special notice. Everyone must have felt that the mere reception of food in the mouth, and its contact with the tongue and palate, excites the secretion of this juice, which is always supplied in quantities sufficient to reduce the food to a digestible pulp, provided that the operation of mastication be continued to the necessary degree. But even though through undue greediness, haste, neglect, or ignorance, the food be sent into the stomach after imperfect mastication, nature has so ordered it, that the salivary glands continue to secrete their proper juice, which, being swallowed, mixes in the stomach with the food, which ought to have been saturated with it in the process of mastication in the mouth, so that this stomachic insalivation is a provision of nature, if not to prevent, at least in some degree to mitigate, the injurious effects of too greedy or too hasty eating.

It further appears by some curious physiological experiments, that food deposited in the stomach, without passing through the mouth at all, as it may be by an artificial opening, actually reacts upon the salivary glands, causing the secretion of saliva, which being swallowed and taken into the stomach, supplies the food with that juice, which it ought to and would have acquired in the process of mastication.

663. **Admirable Uses of the Salivary Glands.**—It has been well observed that the salivary glands, not content with discharging their functions, when directly excited by food in the mouth, are constantly, so to speak, on the watch to be useful,

and often begin to act the moment the expectation or desire of particular food is entertained. Everyone has felt how the mouth waters at the mere mention of certain agreeable aliments.*

664. **Their Number and Position.**—In the case of man, there are three pairs of glands placed symmetrically at either side of the median plane ; these are, first, the *parotid glands*, situated behind the lower jaw and in front of the ear, the *submaxillary glands*, which are lodged immediately under the angle of the lower jaw, and, in fine, the *sublingual glands*, already mentioned, placed immediately under the tongue in the fleshy part of the jaw. Each of these glands communicates with the mouth by a special conduit, pouring the saliva into it. The saliva furnished by each pair of these glands, has a different quality ; that secreted by the parotids being more, and that by the submaxillary less watery, than the saliva of the sublingual glands.

Besides these, numerous other less voluminous glands, all of racemose or clustered structure, surround the mouth, such as the glands of the cheeks, lips, inferior surface of the tongue, and the velum palati, independently of the numerous follicles appropriated to the secretion of mucus.

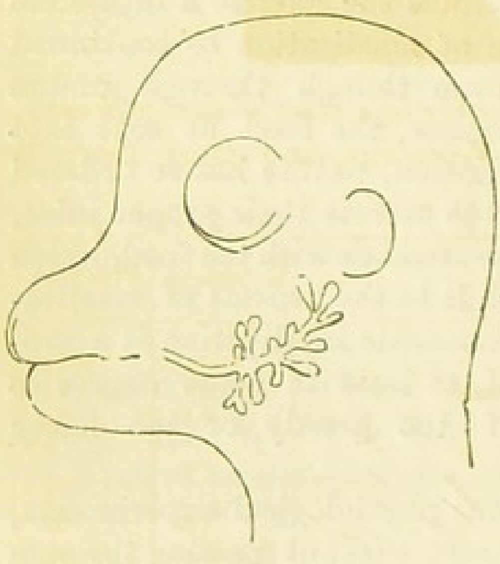


Fig. 370.
FIRST APPEARANCE OF THE PAROTID GLAND IN A SHEEP.

The relative position of the submaxillary and sublingual salivary glands is shown in fig. 366. The structure of the great salivary glands may be illustrated by figs. 370 and 371, which represent the development of the parotid gland of a sheep (reproduced from Müller).

665. **The Quantity of Saliva** secreted during meals is much greater than in the intervals between them, and is generally in direct proportion to the hardness and dryness of the food. It is estimated that the average quantity secreted by an adult in twenty-four hours is from fifteen to twenty ounces.

* Johnston's Chemistry of Common Life, vol. i., p. 364.

666. **Saliva** is a viscous, inodorous liquid, imperfectly transparent, and always alkaline during the reception and mas-

Fig. 371.

LOBULES OF THE GLAND WITH SALIVARY DUCTS IN A MORE ADVANCED STAGE.

tication of food. Its analysis by Berzelius, and more recently by Frerichs, is as follows :

In 10,000 Parts of Saliva.	Berzelius.	Frerichs.
Water	9929	9941
Organic matter (ptyaline or salivary diastase) . .	29	14
Mucus and epithelium	14	21
Fatty matter	..	1
Alkaline lactates	9	..
Sulpho-cyanuret of potassium	..	1
Divers salts	19	22
	10,000	10,000

667. **Ptyaline.**—Of the several solid substances held in solution by saliva, the most important by far, in its effects upon digestion, is that to which Berzelius gave the name *ptyaline* (from the Greek word for saliva), as being the essential principle of that secretion. Owing to the peculiar process by which that eminent chemist obtained ptyaline, he failed to discover its peculiar physiological virtue, the high temperature to which it was exposed having the effect of altogether effacing that property. More recently Leuchs prepared it by

precipitation in alcohol, by which, no elevation of temperature being necessary, the physiological property was unimpaired.

Ptyaline owes its physiological importance to its effect on the starch of vegetable food. It produces upon that substance two successive changes. By the first it converts it into a gum-like substance, called dextrine, from an optical property by which it produces right-handed polarisation on light transmitted through it. (See "Handbook of Natural Philosophy," Optics, § 294.) By the next, it converts this dextrine into another substance, called glucose, or grape-sugar. Dextrine differs from starch only in its state of aggregation, but glucose differs in its constituents, including one equivalent of oxygen and one of hydrogen not in the starch or dextrine.

In consequence of this property, discovered by Leuchs, and rendered still more manifest by the experiments of Mialhe, the name *salivary diastase* has been substituted for ptyaline; diastase being that constituent of malt in virtue of which the formation of grape-sugar or glucose is accelerated during the fermentation of the worts.

668. **Starch** is one of the most universally prevalent constituents of vegetable aliment. It occurs abundantly in the grain and seeds of all cereals, and in many roots, such as the potato and arrow-root. It is also found, according to Liebig, in unripe apples and pears, and in the seeds of leguminous plants. It is most easily obtained pure from potatoes.

Starch itself is insoluble, and would therefore be indigestible; hence the importance of the chemical change produced upon it by the saliva, by which it is converted into grape-sugar, a substance eminently soluble. It belongs to the non-nitrogenised class of aliments, and therefore supplies no elements for the increase of the body or its organs, being useful chiefly in the production of animal heat. It composes a part of the fuel of the organism. Whatever part of it is not consumed in organic combustion accumulates in the form of fat.

669. **The Salivary Glands** do not all secrete saliva of the same quality. M. Lassaigne ascertained that the saliva of the parotid gland of the horse has not the power of converting starch into sugar. M. Bernard showed that the same is true of the saliva secreted separately and conjointly by the parotid and sublingual glands of the dog. It appears from these and other results that the virtue by which the saliva renders vegetable food (including bread) digestible, is a property of the

products of all the glands of the mouth taken collectively, and that the peculiar ferment of ptyaline proceeds from the smaller rather than from the chief glands.

As the conversion of starch into sugar by ptyaline is not instantaneous, but on the contrary requires a considerable interval, and as the sojourn of food in the mouth is much more brief, it follows that the saccharine transformation must take place chiefly in the stomach, a fact which raised some doubts as to the phenomenon. The alkalinity of the saliva is a condition indispensable to the saccharine change. Now the moment the pulp enters the stomach it is brought under the action of the gastric juice, which is acid. The first effect of this must be the neutralisation of the alkaline pulp, and the next its acquisition of the acid principle. It was therefore contended that such a change would at once arrest its saccharification. This reasoning, however, has been proved erroneous: first, by the experiments of Schwann, which were repeated and varied by Jacobowitsch, Frerichs, and others, and which can be easily reproduced. The acidification of the pulp only retards, but does not arrest its saccharification; and as it remains for some hours in the stomach, abundant time is given for the completion of the latter process.

In relation to these effects it may be observed, that in the case of ruminants, which derive their nourishment chiefly from feculent aliments, the food is largely supplied with saliva, being repeatedly masticated in being transferred from stomach to stomach.

670. That neither the fatty parts of the food, such as fat, oil, or butter, nor the nitrogenous aliments, are affected by the saliva, is proved by experiments on artificial digestion. The part played, therefore, by that fluid is strictly limited to the specific action of the ptyaline on the feculent constituents, and the general dissolving action of the large proportion of water of which it consists. With carnivora, therefore, which consume in general no feculent food, it acts merely as a mechanical agent in converting the food into pulp, and thus facilitating deglutition.

Cases have occurred in disease in which, not only insalivation, but all mastication has been suspended for months. In the *Maison de Santé* of Dr. Blanche, at Passy, near Paris, an insane patient obstinately refused to swallow food of any kind, and was for many months nourished altogether by food passed artificially into the stomach, through the œsophagus, without deglutition. This patient did not even swallow his saliva. It was necessary to remove from his mouth, two or three times a day, the accumulation of saliva by which it was distended. Food consisting of a due proportion of nitrogenised, fatty, saccharine, and feculent aliments, united

with a certain quantity of vegetable diastase, to supply the place of saliva, was passed into the stomach by means of a tube. Nevertheless the physical health of this individual was perfect, and even his weight augmented under this regimen. This singular phenomenon may perhaps be explained by the fact which will presently appear, that the feculent aliments which resist stomachal digestion encounter agents lower down in the canal which act upon them.

671. **Stomachal Digestion.**—The stomach, as already explained, is a membranous bag, placed across the upper part of the cavity of the abdomen, and almost immediately below the diaphragm. It has the form of a bagpipe, and it is with the stomach of animals having this shape that the air reservoir of the bagpipe is made.

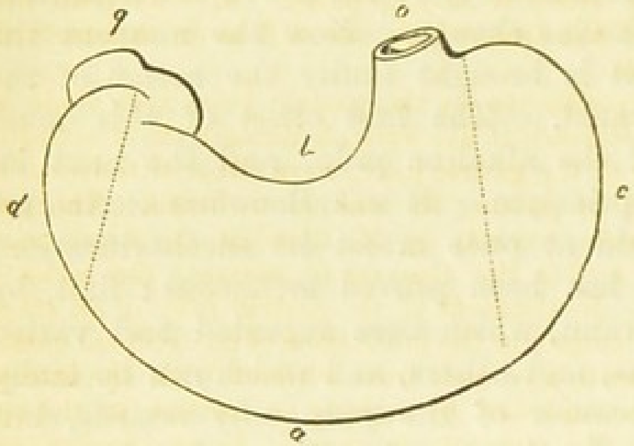


Fig. 372.

When distended, its shape is that which is represented in outline in fig. 372.

The left side, *c*, is called the great cul de sac, or fundus, the right, *d*, the small cul de sac, or antrum pylori. The lower part, *a*, is called the great curvature, and the upper, *b*, the lesser curvature. The opening *o* is united to the lower end of the œsophagus, at or near the point where the latter passes through the diaphragm. This, which is the entrance to the stomach, is called the cardia, or cardiac orifice. The opening, *q*, on the right, leads to the duodenum, and, as already explained, is called the pylorus. The stomach is considered as consisting of three regions, limited by the dotted lines in the figure. The left, *c*, is called the great or splenic end ; the right, *d*, or smaller end, is called the pyloric region.

672. **Gastric Juice.**—The stomach, like all other parts of the intestines, is lined by the mucous membrane, which, as elsewhere, secretes the liquid called mucus, by which its surface is everywhere and at all times lubricated. When the stomach is empty, and the process of digestion suspended, this mucus is the only liquid secreted. But when any substance is introduced into the stomach, whether it be food or not, it excites a peculiar secretion called the *gastric juice*, which plays an important part in stomachal digestion.

The gastric juice is a colourless, limpid liquid, having a faint odour characteristic of the animal which secretes it, and a slightly saltish flavour. Its specific gravity differs but little from that of water, being heavier than it in the human

organism by no more than a 20th per cent. Tested by turmeric paper it betrays the acid quality. Submitted to analysis it is found to contain 99 per cent. of water, combined in a minute proportion with certain salts, a free acid, called *lactic acid*, and a peculiar organic substance which has received the name of *pepsine*.

The acidity of the gastric juice was, until a late period, ascribed to the presence of hydrochloric acid. This, however, was shown to be an error arising from the process by which it was prepared. M. Chevreuil first showed the true character of the acid, which was still more satisfactorily demonstrated by M. Lehmann.

The first physiological experiments on the gastric juice were made by forcing dry sponges into the stomach of live animals through the œsophagus. These becoming saturated with the gastric juice, were either withdrawn by means of cords, or removed by putting the animal to death. The processes, however, practised more recently by M. Blondlot are much more effectual, inasmuch as they enable the observer to examine the series of phenomena arising from the development of the gastric juice in all stages of digestion. This process consists in the production of an artificial gastric fistula, by which a communication is made from without with the interior of the stomach. This is accomplished by making an incision in the epigastric region, drawing out the stomach, opening it by an incision, and fixing the edges of such incision to the lips of the abdominal incision by suture. At the end of some days, adhesive inflammation has ensued, and the opening of the stomach is permanently connected with the abdominal opening, so that the communication from without is established. A canula is inserted in the opening, which is stopped by a cork. By the aid of this ingenious contrivance, the gastric juice can be produced at will, and aliments can be introduced into and withdrawn from the stomach at all stages of digestion, so as to enable the physiologist to study the series of transformations which they undergo.

In some rare and exceptional cases, pathological lesions have produced fistulæ of the same kind in the human patient, so that similar observations have been made in the human stomach in the process of digestion.

673. A multitude of glands, simple and compound, of different structures, are diffused everywhere through the coats of the stomach. It is, however, chiefly in the pyloric region that the compound glands are found ; those round the cardiac opening and along the lesser curvature being chiefly an agglomeration of mucous follicles. It is probable that these different glands secrete different qualities of juice, as is ascertained to be the case in the salivary glands ; but this fact has not been established by experiment, the gastric juice thus obtained being always the result of the general secretion of the organ. From analogies derived from observation on ruminating animals, it seems probable, however, that the most efficacious part of the gastric juice is developed in the pyloric region, since it is found

that in ruminants the gastric juice, properly so called, is secreted exclusively in the last stomach, which corresponds to the pyloric side of the human stomach.

674. **The Constituents of the Gastric Juice** which exercise the most important influence on digestion are the *lactic acid* and the *pepsine*. Other acids, such as acetic and butyric, are, it is true, sometimes found in the stomach, but these are not properly secreted, but result from the phenomena of digestion, and are never found except when this function is in progress. To obtain the gastric juice in its normal condition, unmixed with foreign or accidental constituents, it should therefore be taken from the stomach of an animal in which the process of digestion is suspended.

675. **Pepsine**, called also by some physiologists *chymosine*, and by others *gasterase*, is a nitrogenised substance having some analogy with albumen, and having the character of a ferment. It is soluble in water, and insoluble in alcohol, which precipitates it. It is also precipitated by tannin, and by the acetate of lead. It differs from albumen in this, that its aqueous solution is not rendered turbid by ebullition; nevertheless, though not coagulated, an elevated temperature deprives it of its characteristic properties, and hence have arisen some errors of physiologists, who have experimented on the gastric juice at high temperatures.

The best process for producing pure pepsine is that of M. Payen, who proceeds thus :—He procures the gastric juice of a dog, taken from the stomach, as usual, by an artificial fistula. The pepsine is precipitated by alcohol, and with it some small proportion of albumen and mucus. This precipitate is treated with water, which dissolves only the pepsine. The solution of pepsine is again precipitated by alcohol, and the precipitate dried at a temperature of 100°.

The following is the analysis of the gastric juices of the horse and dog :—

	HORSE. Tiedemann&Gmelin.	DOG. Frerichs.
Water	98·10	98·85
Organic matter	1·05	0·72
Salts	0·55	0·43

The phenomena developed in stomachic digestion by the action of the gastric juice upon the food, are ascertained partly by artificial digestion,

and partly by observing the state of the food taken directly from the animal stomach in different stages of digestion.

676. **Artificial Digestion** is produced by merely exposing the different kinds of aliment to the gastric juice, natural or artificial, at the temperature of the living body. In all such experiments it is remarked that the aliments, when divided into very small fragments, are much more quickly dissolved by the gastric juice than when exposed to it in larger pieces. The utility of mastication, and of the mechanical action of the stomach is thus rendered evident. Artificial gastric juice, for experimental purposes, may be produced by dissolving pepsine in acidulated water.

677. Aliments consisting of fibrine, gluten, or coagulated albumen, submitted to artificial digestion, are dissolved after the lapse of some hours, the product of the solution being the same in each case.

When the same experiment is made with caseine, coagulation first ensues, produced by the acidity of the juice. To this succeeds, by degrees, disintegration and finally complete solution. The ultimate product is no longer coagulable either by acids or by heat.

Liquid albumen is rendered slightly turbid by the gastric juice, though it cannot be said to be coagulated. This turbid appearance, however, soon ceases, and at the end of five or six hours it undergoes, like other albuminous substances, an isomeric * transformation. It is no longer coagulable either by acids or by heat.

When gelatine, obtained in the jelly of meat or bones, is exposed to the action of the gastric juice, it is soon dissolved, forming a clear brown liquid. The product, however, is not a pure and simple solution, since, when concentrated by evaporation, it is found to have lost the property which it possessed of resuming the state of jelly when cold. It is not certainly known whether the production of the solution of gelatine by the gastric juice is identical with the results of the like solutions of the other aliments above mentioned.

It follows, therefore, in general, that fibrine, gluten, albumen in the solid or liquid state, and caseine, are dissolved and metamorphosed by the gastric juice into an identical substance. This final result of the process has the same chemical

* Substances are said to undergo isomeric changes when their properties are altered, while their chemical constituents remain the same.

composition as the albuminous substances from whence it proceeds, as has been proved by the analyses of M. Lehmann. Like albuminous substances in general, this forms xanthoproteic acid when heated with nitric acid. It is precipitated by alcohol, tannin, and corrosive sublimate. It differs from albumen properly so called, inasmuch as it is not precipitated by acids or coagulated by heat.

This common product of the stomachic digestion of albuminous substances is called *peptone* by Lehmann, and *albuminose* by Mialhe.

678. The alimentary matters which are not albuminous are not attacked or dissolved by the gastric juice. Thus fatty substances and oil remain altogether unaltered by it. In the artificial digestion of meat, the fat is seen floating at the surface in an oily stratum. Neither starch nor sugar is affected by the gastric juice in any manner different from that in which they are affected by most of the juices of the economy. Cane-sugar is transformed into grape-sugar, and in that state is absorbed; but this change does not take place in the stomach, being produced subsequently in the small intestine. Neither gum nor pectine are affected by the gastric juice.

All organic substances soluble in water, such as the chlorides and the alkaline phosphates and sulphates, are also soluble in the gastric juice, their solution being facilitated by the aqueous drinks which they generally encounter in the stomach. The phosphate of magnesia and such salts of lime, iron, and other similar principles, which are scarcely soluble in water, are rendered so by the acidity of the gastric juice.

In comparing artificial with natural digestion, it is important to remark, that though their ultimate results are identical, the natural digestion is always more prompt than the artificial. Numerous experiments made by M. Blondlot demonstrate this.

679. **Natural Stomachal Digestion.**—If the stomach of the animal be opened at different periods of the process of digestion, and its contents examined, they will be found to consist of a sort of paste, pulp, or brothy substance called *chyme*, composed of the food combined with the gastric and salivary juices, and which will be more or less complex according to the food which the animal has taken, and more or less liquefied according to the quantity of drink which it may have swallowed, and according to the progress, more or less advanced, of the digestive process. If we suppose, for example, that the animal has taken a mixed food, consisting of milk, bread, meat, potatoes, and vegetables, we shall find, in the first place, the contents of the

stomach to consist of starch not yet transformed, and which will not be so until they pass into the intestine, with dextrine and sugar proceeding from the partial action of the saliva upon a certain quantity of starch. The salivary action, which commences in the mouth, is continued in the stomach, but is not completed until after the food has passed through the pylorus into the intestine. Much of the food will also be found in the stomach, not yet modified by either the saliva or the gastric juice, consisting of fat, which resists both of these juices; albuminous substances, such as fibrine or caseine in different degrees of solution; but if the examination take place two or three hours after a meal, such substances will have in a great degree disappeared, being absorbed by the coats of the stomach. A considerable quantity of the constituents of food will also be found, which are not susceptible of conversion either by the saliva or by the gastric juice, or even by any of the juices secreted in the lower parts of the alimentary canal, such as cellular substance, vegetable fibre, grains of starch which have not been broken, fragments of tendons, and so on.

Gastric juice, not yet combined with the food, and lactic acid, will also be found. A considerable quantity of the latter acid will also be accumulated, proceeding from the decomposition of milk-sugar, and other saccharine principles of the food. This acid also sometimes proceeds from the starch of the food, transformed into grape-sugar in the stomach. Acetic acid, proceeding from the peculiar fermentation of sugar, is also sometimes found in the products of stomachal digestion. The same acid also proceeds from wine and alcoholic liquors, especially when taken in excess.

680. In comparing the effects of artificial digestion produced in phials, with the natural digestion of the stomach, erroneous inferences may be drawn if the peculiar absorbing power of the coats of the stomach be not taken into account. In the artificial process, the products resulting from the gradual combination of the gastric juice with the food still remain in the phial, and may probably, by their continued presence, produce important modifications in the results. But in the stomach the food combined with the gastric juice being in immediate contact with an absorbing surface, passes, by absorption, into the vascular system, and is thus removed from the stomach, so as to prevent the occurrence of those secondary effects which would be manifested in artificial digestion.

An example of the importance of this distinction was presented in the experimentary researches of M. Blondlot, who, having introduced into the stomach of an animal through a gastric fistula liquid albumen, found that it disappeared almost immediately by absorption, whereas the same liquid albumen, put into contact with the gastric juice in the phials used in artificial digestion, was transformed at the end of five or six hours into the substance incoagulable by heat called peptone. It is, therefore, extremely probable that the liquid albumen taken into the stomach is always prevented from undergoing the metamorphosis by prompt absorption; and that, consequently, the only substances transformed into peptone, or albuminose, in the living stomach, are solid albuminous matter, such as fibrine, coagulated albumen, whether animal or vegetable, leguminous gluten, and so on. It must be added, however, that albumen in the liquid state is scarcely ever taken into the human stomach—the animal substances on which man feeds being submitted generally to a culinary process which removes that principle.

681. **Digestibility of Food.**—In determining the relative digestibility of different species of food, a question often proposed to the medical practitioner, it is important to take into consideration the fact that the process of digestion is not confined to the stomach, but is carried on with more or less energy throughout the whole extent of the intestinal canal. It would, therefore, be a great error to assume that food which passes easily and promptly through the stomach, is, therefore, more digestible than other forms of food which are retained there for a more considerable time. Nature has so ordered it that food which is not attacked by the gastric juice, but which is susceptible, either exclusively or principally, of intestinal digestion, soon passes from the stomach to those parts of the alimentary canal where it is destined to meet with juices capable of converting it. Aliment, therefore, which is most digestible is that which most promptly yields to the action of the digestive juices, in whatever part of the canal it may be affected by them.

Among the aliments which pass most promptly through the stomach, are those of vegetable food. If an animal be supplied at the same meal with meat and vegetables, the stomach will retain the former, while the latter passes on. Drinks of every sort, which have no need of combination with the gastric juice, and which are absorbed indifferently in all parts of the alimentary canal, pass very promptly through the stomach.

682. It may be generally stated that vegetable food is less digestible than animal, as indeed must be expected from considering that the latter is in a state more assimilated to the organs of the body than the former. In vegetable food are

found the most refractory constituents relatively to the digestive functions, such as cellular fibre, the envelopes of grapes, lentils, peas, beans, apples, pears, and fruit generally. Most vegetables which have not been either mashed in the culinary process, or strongly masticated in the mouth, are found to be presented in their natural state in defecation. Among the most indigestible food taken into the stomach are truffles and mushrooms.

683. There are some sorts of aliments which not only are incapable of stomachal digestion, but, by their continuance in the stomach, obstruct the digestion of other forms of food, especially when taken in any considerable quantity. Such are animal fat generally, butter, oil, the oily principle of walnuts, almonds, hazel-nuts, and olives. These and the like, even when they pass from the stomach to the intestine, are extremely difficult of digestion, and are incapable of any but the slowest absorption. When taken in any considerable quantity, they pass through the alimentary canal altogether undigested.

684. So far as relates to the relative digestibility of the different constituents of food, determined by the mean time required for chylification, the following are the results of the experiments made by M. Blondlot upon dogs by means of the gastric fistula.

ALIMENT.	TIME OF DIGESTION.	
	Hours.	Minutes.
Fibrine	1	30
Gluten (cooked or baked)	2	0
Caseine	3	30
Coagulated albumen	6	0
Fibrous tissues (tendons, ligaments, &c.)	10	0

685. **Experiments of Dr. Beaumont.**— Among the physiological experiments on digestion, those of Dr. Beaumont, an American physician, merit especial notice. These were made upon a young man whose stomach had been opened by a gunshot wound, which, though cicatrised, still remained sufficiently open to render the stomach distinctly visible. Dr. Beaumont ascertained that, immediately on the arrival of food in the stomach, the secretion of the gastric juice commenced, and, by its intermixture with that fluid, after a sufficient interval, the food was converted into chyme ; he not only took out of the stomach of this man the mixture of food and gastric juice and saw it converted into chyme separate from

his body, but he was enabled, by means of a tube, to procure a certain quantity of the gastric juice, which he saw oozing through the sides of the stomach, and with this juice, like Spallanzani, he succeeded in exhibiting artificial digestion. He mixed it with pieces of beef, properly triturated, and exposing the mixture to the proper temperature, saw it converted into chyme.

The following are among the results obtained by observations on this patient :—

Aliments.	Time of Digestion.	
	Hours.	Minutes.
Veal, beef, mutton, and pork (whether boiled or fried)	4	0
Ditto (roasted) . . .	3	30
Fowl—brown (goose, duck, &c.)	3	30
Fowl—white (chicken, pheasant, &c.) . . .	3	0
Fish	2	30

686. Much uncertainty attends the relative digestibility of feculent aliments, such as bread, pastry, potatoes, &c. None of these being completely digested, and some not at all, in the stomach, their digestion is principally or exclusively intestinal.

The duration of stomachal digestion is subject to great variation. In the case of substances susceptible of digestion by the gastric juice, the process is generally completed in three or four hours. Persons devoted to mental occupations, to study, and, consequently, of sedentary habits, have generally languid digestions, the food often remaining in the stomach unassimilated for six or eight hours, and producing a certain sense of lassitude, which only ceases upon the completion of digestion. Exercise in general favours stomachal digestion, provided it be restrained within moderate limits. Violent exercise, with a full stomach, commonly produces indigestion. The process of digestion is quicker when waking than when sleeping.

687. **Intestinal Digestion.**—After passing from the stomach through the pylorus (fig. 367) the food is propelled slowly and successively along the duodenum, the small intestine, and the colon to the rectum. In its progress it is exposed to the action of the pancreatic juice and the bile, which are poured into the duodenum from the pancreas and the liver, and to that of the intestinal juices secreted by glands which prevail in all parts of the intestine. Its impregnation by these several juices produces

effects upon it by which certain constituents which have received the action of the saliva and the gastric juice are rendered susceptible of absorption, and by that process pass into the organism, through the coats of the intestine. The unconverted residuum, having resisted all these agents, descends to the rectum, whence it is expelled in defecation.

688. **The Pancreas,** so called from two Greek words (*πᾶν*, *pan*, all; *κρέας*, *kreas*, flesh), is a narrow flat gland extending across the abdomen under the stomach. Its form and position, with the contiguous parts, are shown in fig. 373, reproduced after Tiedemann, with modifications by Quain.

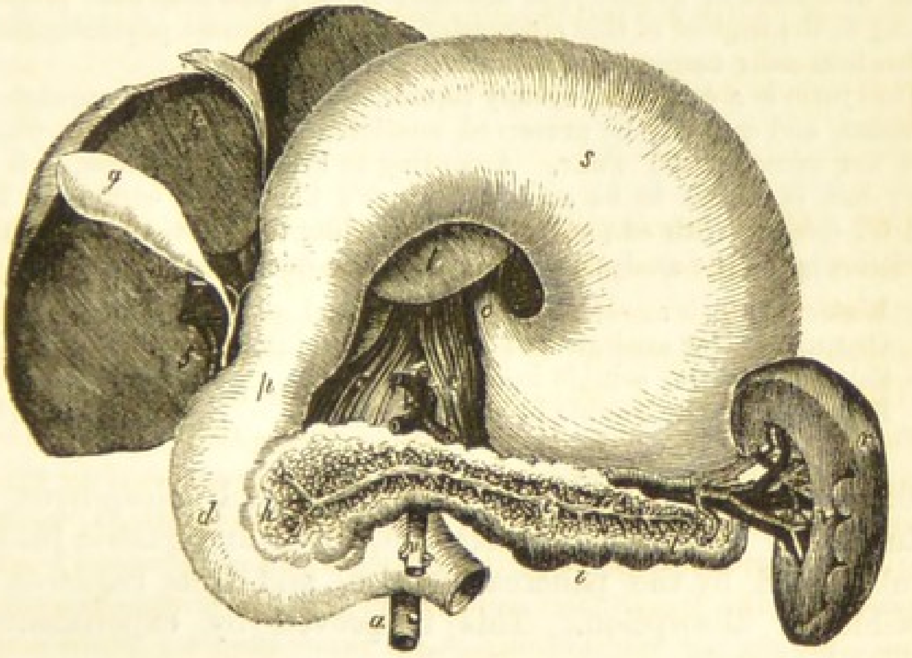


Fig. 373.

STOMACH, LIVER, AND PANCREAS.

In this figure the liver and stomach are turned up to display the duodenum, pancreas, spleen, and their appendages.

l The under surface of the liver.
g Gall-bladder.
f Common bile duct, formed by the union of the cystic duct leading from the gall-bladder and the hepatic duct from the liver.
o The cardiac end of the stomach, proceeding from the œsophagus.
s The under surface of the stomach.
p Pyloric end of the stomach.
d Duodenum.
h Head,
t Tail and
i The body of the pancreas, the substance of which is removed in front so as to show the pancreatic duct, *e* and its ramifications.
r The spleen.
v The hilus at which the blood-vessels enter.
c The crura of the diaphragm.
n The superior mesenteric artery.
a The aorta.

The pancreatic duct (fig. 373) traverses the whole length of the gland,

from which it drains the juice, and, coming into juxtaposition with the common bile duct, accompanies it to the duodenum, before reaching which it bifurcates, the upper branch coalescing with the bile duct, and entering the duodenum by a common orifice, and the lower branch entering by a second orifice about an inch lower down. The pancreatic juice mingled with the bile is therefore poured into the duodenum at the upper embouchure, and that juice alone at the lower.

689. **The Pancreatic Juice** may be obtained for artificial digestion by means of a pancreatic fistula similar to the gastric fistula already mentioned. This method has been practised with complete success by M. Bernard.

In obtaining the pancreatic juice in this manner it should be taken from the animal soon after a meal, since the juice secreted after digestion, though more abundant in quantity, is deficient in the characteristic properties. Owing to the neglect of this circumstance, some eminent physiologists have fallen into error respecting the functions of this juice.

This juice is a colourless syrupy liquid. When warm, it coagulates like albumen, and can only be preserved unaltered by keeping it at a temperature not exceeding 50° Fahr. According to French authorities, it is alkaline; but is stated to be acid in Turner's Chemistry, edited by Liebig and W. Gregory (8th ed., p. 1294). According to Tiedemann and Gmelin, the following is the analysis of the pancreatic juice of a dog:

Water	91·72
Organic matter analogous to albumen (and insoluble salts)	3·55
Salts and matter soluble in alcohol	3·86
Salts and matter soluble in water	1·53

690. **Digestive Effects.**—The fatty and oleaginous constituents of food which resist the saliva and gastric juice are emulsionised by the pancreatic juice, and thus rendered susceptible of absorption. This is proved by experiments on artificial digestion.

When ligatures are put on the pancreatic ducts, so as to intercept the supply of that juice to the duodenum, the fatty and oily parts of the aliment pass unaltered in defecation.

In the rabbit, the pancreatic duct enters the intestine at ten or twelve inches below the embouchure of the bile duct. It is accordingly found that, while the part of the intestine between the embouchure of the bile duct and that of the pancreatic duct is full of fatty matter in its unaltered state, that which has passed below the pancreatic duct is emulsionised; which proves that the bile has no part in producing this change. The lymphatics surrounding the intestine below the pancreatic duct are found charged with emulsionised fat, from which those around that part of it which is above the embouchure of the duct are comparatively exempt.

Eisenmann found that patients suffering under maladies of the pancreas grew rapidly lean. Bernard, having destroyed the action of the pancreas of dogs, found that they grew lean, and that the fatty matter of the food passed from them unaltered in defecation.

691. The conversion of the feculent constituent of food into grape-sugar, which, as we have shown, is commenced by insalivation in the mouth, and continued by the same agency in the stomach, is not completed there. A quantity of starch, still unconverted, is always carried with the chyme through the pylorus into the duodenum, especially in the case of individuals who observe a regimen chiefly or exclusively vegetable, and in that of herbivora generally. The pancreatic juice acts upon this undigested starch in the same manner as the saliva, and converts it into glucose. This has been recently demonstrated by MM. Sandras, Bouchardat, and Lenz.

692. **The Liver** is the gland which secretes bile ; it constitutes part of the organism of all vertebrates, and, in a more or less developed state, of the non-vertebrates. It is placed immediately under the diaphragm, to which the form of its upper surface is adapted, lying above the stomach and other intestines (fig. 373,[1]). It is the largest gland in the body, and the most voluminous of the abdominal viscera, measuring ten or twelve inches across, from side to side, six or seven from front to back, and about three inches vertically at its thickest part. Its average weight, in the adult, is about 60 oz.

693. **The Bile.**—The juice which the liver secretes is drained from that organ by a duct, called the *common bile duct*, which discharges it into the duodenum (fig. 365). It plays a double part in the organism, being partly excrementitious and evacuated with the undigested residuum of the food, to which it imparts a brown colour, and chiefly an agent in the development of the chemical phenomenon of digestion. It is in the latter character that we shall view it here.

694. The bile is a liquid, slightly alkaline, of a greenish-brown colour, and a taste at once sweet and bitter. Like all the other visceral juices it contains a large proportion, not less than 86 per cent., of water. Combined with this, it contains two organic salts, called *cholate* and *choleate of soda ;* the organic acids which characterise these salts being consequently called *cholic* and *choleic* acids. They differ slightly in this, that the latter contains sulphur, from which the former is free. These acids are sometimes called, the one *non-sulphuretted bilic acid* (or glycocholic acid), and the other *sulphuretted bilic acid* (or taurocholic acid).

695. Besides these alkaline constituents, the bile contains trhee nitro-

genised colouring substances. First, a brown constituent, called *cholepyrrhine*, or *biliphœine*; secondly, a green constituent called *biliverdine*; and, thirdly, a yellow constituent called *bilifulvine*. These principles, separately treated, are insoluble in water. They are dissolved, however, in the bile by the influence of the choleate of soda. Some fatty matters also enter into the composition of bile, called cholesterine, oleine, and margarine; and, as with all the intestinal juices, mucus forms a part. The following is the analysis of human bile by Frerichs:

Water	86·0
Cholate and choleate of soda	10·2
Cholesterine, oleine, and margarine	0·5
Mucus	2·7
Salts	0·6
	100·0

696. **Digestive Effects.**—The bile is poured into the duodenum, it being that part of the intestines where the process of digestion is most active. It is drained from the liver by a tube called the *hepatic duct*, which unites with another called the *cystic duct*, proceeding from the gall-bladder (373,[g]), their union (373,[f]) forming the *common bile duct*, which enters the duodenum. A part of the bile which flows through the hepatic duct is driven up through the cystic duct into the gall-bladder (373,[g]), which it fills, another part being discharged, drop by drop, through the common bile duct into the duodenum. When food has accumulated in the stomach, and while digestion is in progress there, the bile accumulated in the gall-bladder is discharged through the cystic duct, and from it through the common bile duct into the duodenum, where it awaits the arrival of the chyme descending through the pylorus. That this discharge of the gall-bladder precedes the descent of the digested chyme from the stomach is proved by the fact that, when the animal is opened fasting, the gall-bladder is found full; but, if it be opened an hour or two after a meal, and just before the contents of the stomach pass into the duodenum, the gall-bladder is found empty, and the duodenum thickly coated with bile. The same phenomenon has been observed in the human subject when death has taken place during the process of stomachal digestion. The mechanical force which expels the contents of the gall-bladder into the duodenum is partly the pressure upon it produced by the stomach which lies over it, and partly the contractile action of the gall-bladder itself.

697. The property of the liquid which fills the gall-bladder in animals, in virtue of which it mixes with greasy and oleaginous substances, is, as is well known, rendered available by scourers in their art. This action, however, consists in a mere mechanical mixture, no chemical effect being produced. Lenz has shown that the alkalinity of the bile is too feeble to saponify fat substances in any sensible degree. It seems, therefore, that the bile in the process of digestion only co-operates with the pancreatic juice, in emulsionising fatty oleaginous substances. Its influence, however, even in this respect, appears to be very feeble, not having been perceptible in the experiments of M.

Bernard, already mentioned, on the properties of the pancreatic juice.

The bile produces no effects like those of the pancreatic juice and the saliva upon the feculent principles of the food, and since its effects in emulsionising fat are feeble compared with those of the pancreatic juice, it may be inferred that its effects, taken collectively upon the phenomena of digestion, are much less important than those of the other juices.

698. In experiments made on the living animal when the bile has been altogether diverted from the alimentary canal by means of a biliary fistula, and caused to flow away out of the body, the life of the animal has, nevertheless, been prolonged for many months ; proving that the total suppression of the bile does not produce any disorders in the organism, either as manifest, or as prompt, as does the suppression of either the pancreatic juice or the saliva. This may be easily conceived when it is considered that the pancreatic juice not only emulsionises the fatty parts of the food much more effectually than the bile, but also co-operates with the saliva in the conversion of the feculent parts.

699. **Chylification.**—The mucous membrane which lines the small intestine is covered with a multitude of small follicles, which, like those of the stomach, are connected with glands. These secrete a specific humour, called the *intestinal juice*, which, like the gastric juice, is poured into the intestine and mixed with the chyme, the mixture forming, by the process of intestinal digestion, a milky fluid, called *chyle*, from a Greek word (χυλος, *chulos*) signifying juice. The process, by which this fluid is produced, is called *chylification.*

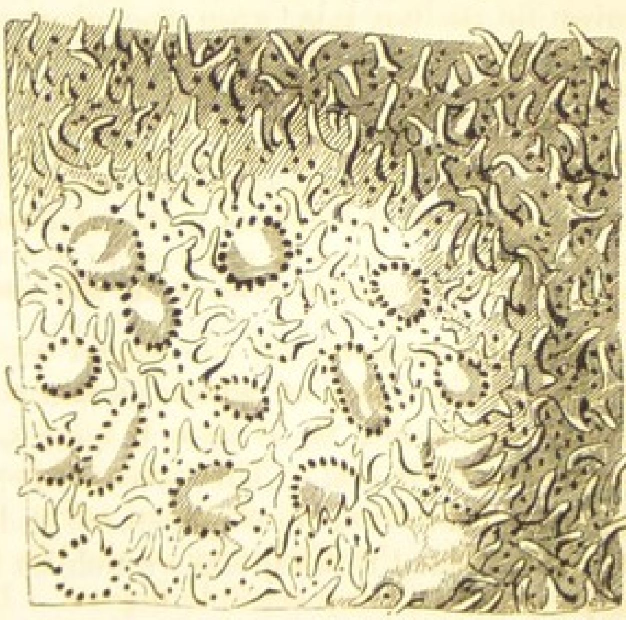


Fig. 374.

700. **Structure of the Inner Surface of the Small Intestine.**—The mucous membrane of the small intestine is arranged in crescentic projections or folds, called *valvulæ conniventes.* They reach half or two-

thirds round the interior of the tube, and are most developed in the jejunum, disappearing in the ileum. Numerous small processes, called *villosities,* also project from every part of the internal surface of the small intestine ; in these commence the *lacteal* vessels, by which the chyle is sucked in and ultimately transmitted to the veins which lead directly into the heart.

The inner surface of the intestine also presents *glands* or *follicles*, which vary in structure and arrangement in different situations.

In fig. 374, reproduced from Boehm, altered by Quain, a magnified view of part of the inner surface of the small intestine is presented, showing the different forms of the individual vesicles, the zones of foramina surrounding the vesicles, and the villosities between the vesicles ; the darker part of the mucous membrane being beset with villi and follicles.

701. **Intestinal Juice.**—Owing to the intermixture of the other juices of the alimentary canal with the intestinal juice, physiologists have encountered some difficulty in isolating the latter so as to ascertain its peculiar functions in the phenomena of digestion. Frerichs, however, succeeded, by drawing out a loop of the small intestine of a cat ; and having pressed the contents out of it by a gentle movement of the fingers, he intercepted from four to eight inches by two ligatures. The intestine being restored to its natural place, the animal was killed after the lapse of from four to six hours, when the intestine included between the ligatures was found filled with intestinal juice, which had been secreted in the interval.

The liquid thus obtained from different parts of the intestine is limpid, transparent, and alkaline. Its filtered solution is rendered opaline by heat. It is precipitated by alcohol and most of the metallic salts. The following are its constituents, according to the analysis of Frerichs :

Water	950·55
Mucus, insoluble in water and epithelium . . .	8·70
Mucus and organic matter, soluble . . .	5·40
Fatty matter	1·95
Chlorides, alkaline sulphates, earthy phosphates, &c.	8·40

But little has been done to ascertain the special digestive properties of the intestinal juice. Frerichs ascribes to it a feeble influence in the conversion of starch and the emulsionising of fat. Lentz obtained results, from which he made a like inference.

702. **Collective Effects of the Digestive Juices.**—The isolated actions of the several juices secreted in the alimentary canal, which have been explained in the preceding paragraphs, are exhibited under conditions artificially produced for the pur-

pose of determining their specific properties severally. In nature, these juices act upon the food simultaneously.

What is known by direct experiment and observation of this collective action is very limited, being necessarily confined to the results deduced from vivisections made on animals in different stages of digestion, and the examination in such cases of the alimentary matter found at different points along the alimentary canal.

The chyme, after remaining some hours in the stomach, during which a part of it is absorbed by the coats of that organ, passes in successive portions into the small intestine. The parts absorbed in the stomach consist of albuminous matter, dissolved by the gastric juice, and starch saccharified and dissolved by the saliva. The portion which passes into the intestine consists of—1°, albuminous matter already dissolved and not yet absorbed; 2°, sugar educed from feculent matter; 3°, feculent matter not yet converted into sugar; 4°, fatty and oleaginous matter unaltered; 5°, small proportions of lactic and sometimes of acetic acid; and 6°, substances which, resisting all the juices, pass through the canal and are expelled.

This mixture, which in the stomach is greyish, is rendered yellowish in the intestine by the bile. Further on, it becomes greenish, and still further on, as it passes to the large intestine, assumes a darker brownish colour.

The acidity of the gastric juice predominates over the alkaline quality of the other juices to such a degree, that the product of digestion continues to show the acid character until it arrives at or near the large intestine, where the alkaline reaction appears.

The acidity of the contents of the small intestine must not, however, be ascribed exclusively to the gastric juice; being due, in part, to the evolution of acids, chiefly lactic and acetic, from the food during digestion.

When the acidity of the food in the intestine is not ultimately neutralised by the alkalinity of the intestinal juices, fermentation and decomposition of the food takes place more or less in the intestine, producing flatulency and sometimes diarrhœa. Nevertheless, all the effects of the bile and the other juices on the intestinal phenomena have not yet been fully explained. It seems to be agreed, however, that the bile, as well as the food, acts as a stimulus on the organs which secrete the intestinal juice, and that it also reacts upon the muscular coating of the bowels, so as to keep up that vermicular action already described in the case of the stomach, and which is called the *peristaltic motion*.

703. **Intestinal Absorption.**—While the chyle is gradually formed, during the passage of the food through the great length of the small intestine, it is at the same time absorbed rapidly by the villosities already described, and conveyed by the lacteals to the blood. In the interior of the intestine, as already described, there is a series of folds or valves, the effect of which appears to be to increase the surface of the intestine, and to retard the progress of the chyme; when the chyme has arrived near the lower extremity of the small intestine, nearly all the

nutritive part of it has been absorbed, and little more than the refuse or unnutritious residuum passes into the large intestine.

704. **Cæcal Phenomena.**—An acid reaction being observed in the matter contained in the cæcum and the adjacent part of the great intestine, it has been inferred that the coats of the cæcum secrete a liquid acid, which exercises an influence in completing the digestion of the albuminous portions of the food, such as tendons, ligaments, and the organic portions of bones which have resisted the gastric juice. This opinion, however, which is unsupported by any satisfactory demonstration, is controverted, no proof being adduced of the presence of any specific gas in the cæcum or in the great intestine, different from those gases which have passed into it with the food from the preceding part of the intestinal canal. The presence of acids in the matter contained in the cæcum is therefore, with greater probability, ascribed to the same causes which produce the like acids in other parts of the intestine.

It is in the cæcum that the unabsorbed residuum of the food begins to acquire the odour characteristic of fæcal matter ; an odour which is repulsive with all animals which live on animal food, but has nothing disagreeable in the case of herbivora. This odour proceeds in part from the decomposition of undigested matter.

705. **Defecated Matter.**—The excrementitious matter, discharged from the great intestine through the rectum, consists of bile, intestinal mucus, and the undigested and unabsorbed residuum of the food The last consists of very various matter, such as the insoluble parts of vegetable aliment, as grain, nuts, apples, and vegetable fibres, a part of the fibrous animal tissues, ligaments, tendons, elastic tissues, the portion of the earthy salts of bones undissolved by the gastric juice, unconverted starch, and the excess of fatty and albuminous substances, when the quantity of these taken into the stomach is disproportionate to the demands of the organism.

706. **Intestinal Gases.**—When the abdomen of a living animal is opened, in whatever stage the process of digestion may be, the intestines are found inflated by gases ; so that, when no longer confined by the walls of the abdomen, they burst forth and escape from the pressure of the fingers in the

attempt to replace them. These gases fill the entire extent of the alimentary canal, from the pylorus to its lower extremity, but are found in a very small proportion in the stomach.

In the healthy subject they proceed from the chemical changes produced in the phenomena of digestion. In disease, the gaseous accumulation is by some ascribed to the presence of gases received into the intestine from the blood-vessels which circulate in the mucous membrane by which it is surrounded.

The stomachal gases include oxygen, but this gas is not present in any of the intestines, where carbonic acid and hydrogen constitute the chief parts of the gaseous constituents. Carburetted, with a small proportion of sulphuretted, hydrogen, is found in a certain proportion in the large intestine. The following is the analysis of the intestinal gases, given by the authorities indicated in the table :—

In 100 Parts.	Stomach. Chevreul and Magendie.	Small Intestine. Chevreul and Magendie.	Large Intestine. Chevreul and Magendie.	Gas expelled by the Anus. Marchand.
Azote	71·45	20·08	51·03	14·0
Oxygen	11·00	..	..	..
Carbonic Acid	14·00	24·39	43·50	44·5
Hydrogen	3·55	55·53	..	25·8
Carburetted Hydrogen	..	..	5·47	15·5
Sulphuretted Hydrogen	..	..	..	1·0

707. **The Food nourishes the Blood, and the Blood nourishes the Body.**—By this brief sketch of the digestive process, the manner in which the wear and tear of the body is repaired will be understood. All the materials necessary to form its various organs and tissues are extracted, in one form or another, from the food in the stomach or in the intestines, and being absorbed by the apparatus provided for that purpose, they are taken, either directly into the veins, or first into the lacteal apparatus and thence into the veins. As yet, however, they only constitute the raw materials out of which the body is to be repaired. These materials are carried with the current of the blood, as already described, first to the right auricle, and thence to the corresponding ventricle of the heart, from which they are transported by the same current to the lungs, where the blood is converted into arterial or nutritive blood, in which state it returns to the heart, and is thence propelled through the system, in each part of which it deposits those peculiar constituents which are proper for its repair. Thus, it gives fibrine to the muscles, lime to the bones, and so

on; not only the quality, but the quantity of each material being nicely adapted to the wants of the several parts, so that each part shall receive in a given time so much of each constituent as it may have lost by vital action in the same time.

708. **Perfection of the Machinery of Digestion.**—How perfect the machinery of digestion is, will be rendered manifest by the fact, that nearly the whole of the food taken into the body is digested and rendered available for its restoration. Thus, a healthy adult man, fully fed, rejects of undigested matter not more than from 4 to 6 ounces daily, of which from 3 to $4\frac{1}{2}$ ounces are water, so that the quantity of dry, solid matter, discharged from the system, as unavailable for its support, does not exceed an ounce and a half per day.*

709. **Constituents of the Body.**—Since the entire substance of the body is derived from the blood, it must necessarily follow that the constituents of the body and blood must be identical, and we accordingly find this to be the case. Nearly 80 per cent. of the blood is water, the remainder consisting of fibrine, albumen, gelatine, fat, sugar, starch, and saline and mineral matter.

According to the calculations of Professor Quetelet, based upon statistical results, it appears that the body of an average man, weighing 154 lbs., consists of the following constituents, viz. :—

		lbs.
Flesh, skin, and blood		18
Fat		6
Bone,	Gelatine	$4\frac{2}{3}$
	Mineral matter	$9\frac{1}{3}$
Water		116
		154

Thus it appears that about $75\frac{1}{2}$ per cent., or a little more than three-fourths of the entire weight of the human body, consists of water, the remainder being dry solid matter, with which the water is combined, and part of which it renders fluid. The total weight of the liquid blood is about 20 lbs. in the case of such an average man as is here supposed, and of this $15\frac{2}{3}$ lbs. is water. That substance, therefore, enters the blood in the same proportion as that in which it enters the entire body. As the whole nutriment of the

* Johnston's Chemistry of Common Life, vol. ii. p. 375.

blood is necessarily contained in the substances held in solution by this $15\frac{2}{3}$ lbs. of water, it follows that the entire stock of nutriment for the maintenance of the body, contained at any given moment in the blood, amounts to no more than $4\frac{1}{3}$ lbs.

Exclusive of the water with which the remainder of the body is impregnated, the entire weight of organised matter contained in it, including flesh, skin, and bones, amounts to only $33\frac{2}{3}$ lbs., and the stock of nutriment by which this is maintained, is only the $4\frac{1}{3}$ lbs. of solid organic matter contained in the blood. This nutritious part of the blood, therefore, is required to maintain and constantly to replace the waste of about eight times its own weight of organised matter in the body. It is evident from this, that the total quantity of organic matter in the blood must be renewed eight times as fast as that which composes the rest of the body.

710. **Mammifers.**—In this division of the animal kingdom, the functions of nutrition and the structure of the alimentary canal are, in their general character, similar to the corresponding functions and parts of the human organism. In particular cases there are, nevertheless, peculiar differences, which merit attention.

711. **Mastication** is an operation common to nearly all mammifers; but the instruments by which it is performed vary with the food upon which they are intended to operate. So complete is this harmony between the organs and the functions, that by the mere inspection of the masticating apparatus, or even by a single tooth, the regimen, habits, and the general structure of the animal to whom it has belonged can be determined.

Thus, by the tooth represented in fig. 375, we can infer with certainty that the animal to which it belonged must have had a bony skeleton fitted to carry such a tooth, and also to support all the parts of its body. Now, such a skeleton could not exist without having a cerebro-spinal axis to protect it. The animal must, therefore, have had a brain and its appendages, a spinal cord and a nervous system; and this brain and nervous system necessarily suggest the existence of organs of sense, establishing a communication between the animal and the external world. The structure of the tooth, moreover, indicates that the animal was provided with a complete circulatory apparatus, and bones sufficiently developed to afford a safe lodgment for such a tooth—a character which is only found in certain quadrupeds. It would therefore be inferred that the animal in question was a quadruped and a mammifer.

Fig. 375.

TOOTH OF A LION.

From the form of the tooth it would also be inferred that it belonged to a carnivorous quadruped, for no graminivorous nor even omnivorous animal has teeth of this form. The food of the animal was, therefore, flesh, and consequently the stomach and intestines must have been formed in such a manner as to digest this aliment; and the animal must have been furnished with organs of locomotion and prehension proper for the seizure of its prey.

Thus pursuing the chain of reasoning from consequence to consequence, based upon the known analogies of nature, we arrive, if not at an exact knowledge of the structure of the individual animal, at least at the discovery of its most salient characters and functions.*

712. Nothing can be more striking than the difference between the masticating apparatus of animals whose nourishment consists of different substances. In those which live on flesh, the molar teeth are compressed and sharp, and so placed as to meet each other like the blades of a scissors; while the canines are largely developed, and the incisors resemble them more or less in form (fig. 376).

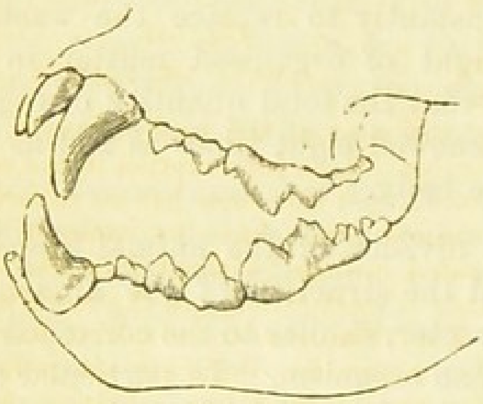


Fig. 376.
TEETH OF A CARNIVOROUS ANIMAL.

713. In those animals which feed on insects the teeth are formed into a series of conical points; those of one jaw fitting between those of the other, like the teeth of wheelwork (fig. 377).

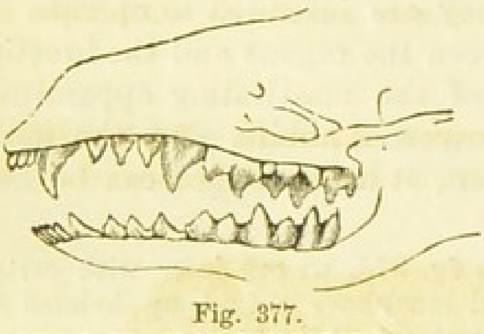


Fig. 377.
TEETH OF AN INSECTIVOROUS ANIMAL.

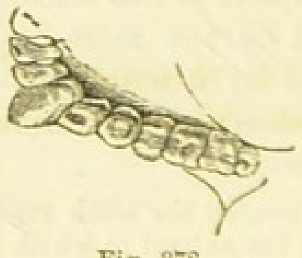


Fig. 378.
TEETH OF A FRUGIVOROUS ANIMAL.

714. When the animal feeds principally on soft fruits, the teeth are principally formed with rounded tubercles, as shown in fig. 378.

When animals feed on vegetable substances more or less hard, such as grain, the teeth are terminated by large flat surfaces (fig. 379); those of one jaw closing upon those of the other, so as to bruise the food between them; by a lateral motion of the jaws one upon the other, imparted by the maxillary muscles, the food is submitted to trituration, like that which grain suffers between two millstones. It has been from this peculiar action that certain teeth have received the name of molars.

Fig. 379.—TEETH OF GRAMINIVOROUS ANIMALS.

* Edwards's Zoology, p. 278.

715. Of all forms of teeth, the molars are the most universally useful, and they are accordingly more prevalent than either incisors or canines. These last, being necessary to seize and devour a living prey, are never wanting in carnivorous species. But they are much less useful, and therefore altogether wanting, in herbivorous species. Thus, in the horse, the canine teeth are merely rudimentary, and the incisors have the structure of molars.

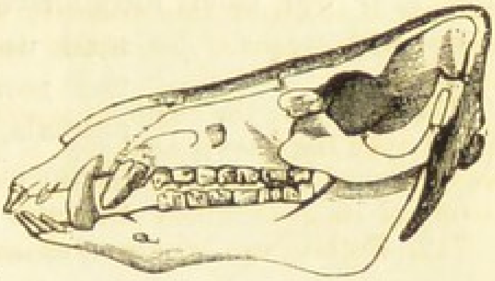


Fig. 380.

JAWS OF THE BOAR.

Sometimes the canines, losing their character of masticators, become a weapon of offence or defence; as, for example, in the case of the boar (fig. 380).

The three classes of teeth—incisor, canine, and molar—are found combined in asses, carnivora, ruminants, and most of the pachydermata. In ruminants and pachydermata there is, besides, an interruption in the series of teeth formed by what are called bars; and this class has no incisors in the upper jaw. The ruminants without horns have no canines. The rodents have only molars and elongated canines, without incisors. The molars, which are the true instruments of mastication, are the teeth which are most rarely absent in animals. The rhinoceros and elephant have no other form of teeth. There are also mammifers destitute altogether of teeth, of which the ant-eaters (Myrmecophaga), pangolins, echidnas—sometimes called spiny ant-eaters—and whales, are examples. The two sides of the upper jaw of the whale, which is keel-shaped, are furnished with two thin transverse serrated lamellæ, called balene or whalebone, consisting of a sort of fibrous horn, fringed at the edges, which serve to retain and strain from the water the minute animals on which these enormous cetaceans feed.

716. **Nutrition of the Lower Animals—Prehension of Food.**—Vegetables receive their nourishment immediately from

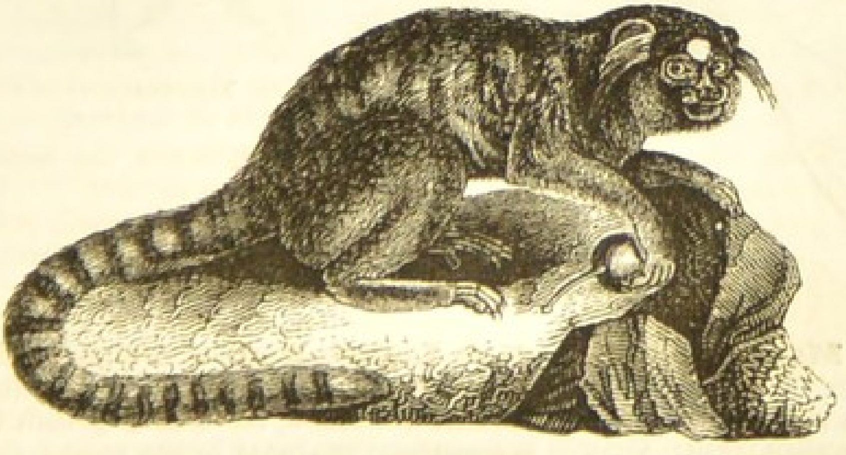


Fig. 381.

suitable material substances which surround them. Animals,

however, are generally obliged to seek their food, and sometimes avail themselves of the use of their prehensile members to lay hold of it and to convey it into their digestive apparatus, and also use their locomotive members to pursue it. Thus, man uses his hands to convey food to the mouth, and many of the inferior animals, such as monkeys, use their prehensile members in the same manner. Certain animals, whose bodily motions are slow, and the opening of the mouth very limited, seize their prey by means of the tongue, which is long and capable of being darted out to a considerable distance ; others, such as the elephant, are provided with a prolongation of the nose or snout, which being very flexible, and having the power of suction, attaches itself to the alimentary objects, which it lifts into its mouth. Others, again, are provided with long and thin processes surrounding the mouth, by which the food is seized, called "palpi," or feelers in the case of insects, (figs. 383, 384), and "tentacula" in the case of mollusca (fig. 385) and polyps (fig. 386).


Fig. 382.

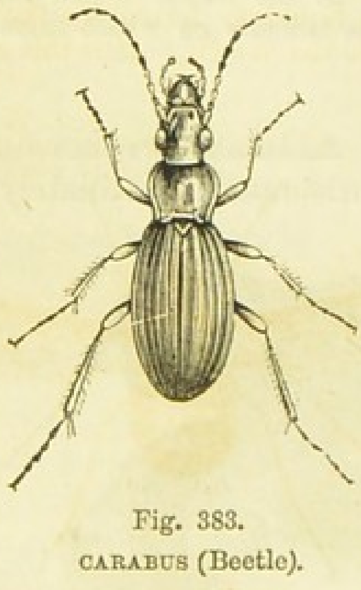


Fig. 383.
CARABUS (Beetle).

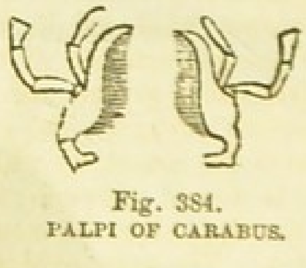


Fig. 384.
PALPI OF CARABUS.

717. **Means of drawing in Liquid Nourishment.** — Liquid nourishment is either poured into the digestive apparatus, into which it descends by its gravity, or is drawn in by suction, or, in fine, by both these operations combined. Suction is sometimes produced by the same action of the chest as that by which air is drawn into the lungs. The suction, however, is often performed by the motion of the tongue in the mouth, which acts in the same manner as the piston does in a syringe. The lips being applied

to the liquid itself, or to whatever contains it, and the tongue being drawn

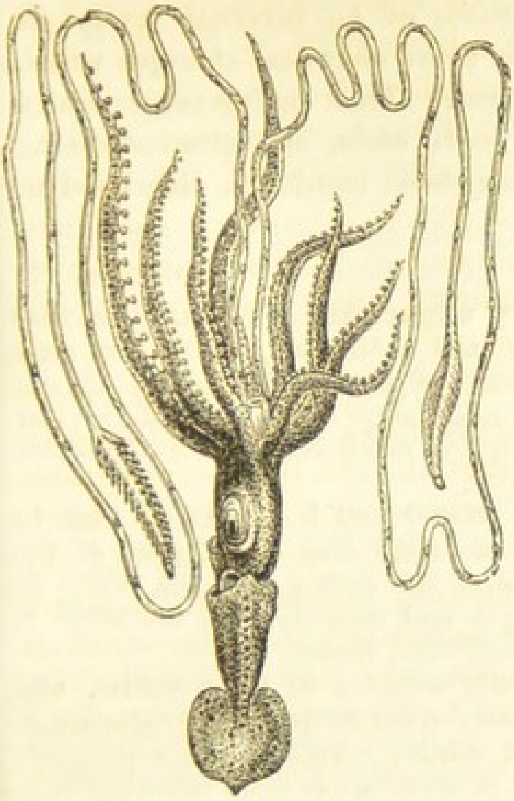


Fig. 385.
MOLLUSCA (Calamary).

Fig. 386.
HYDRA, OR FRESH-WATER POLYP.

back like the piston in the syringe, the liquid is forced by the atmospheric pressure acting from without into the mouth. It is this curious pneumatical experiment which the new-born infant performs when it sucks the mother's breast. The partial vacuum produced in the mouth by the retractation of the tongue, gives effect to the atmospheric pressure acting on the soft integument of the breast, by which the milk is forced through the orifice in the nipple into the mouth of the infant. The same explanation is, of course, applicable to the case of all animals that suckle their young.

Fig. 387.

718. **The Suckers of Insects.**—Some of the inferior animals, among which are many species of insects, draw their nourishment either from juices which they find in plants, or from the bodies of other animals upon which they live as parasites. The opening of the alimentary canal in these species is generally a tube or sucker, by the aid of which they draw the juices, as they would draw them with a syringe.

719. **Digestion of Animals generally.**—In the animal series the digestive apparatus consists of an internal cavity, in which the aliment is submitted to those chemical changes which render it fit to nourish the organism. This cavity is generally tubular in form, and open at both ends, the aliment being taken in at one end, and its undigested residuum dismissed at the other.

720. **Mammifers.—The salivary apparatus** of this class, like that of Man, consists of parotid, maxillary, and sublingual glands. In most of the ruminants the mucous membrane of the cheeks, including the upper and lower molar glands, are considerably developed. Herbivora, subsisting upon feculent food, which requires much saliva for its digestion, have the salivary glands highly developed.

In carnivora the digestive canal is shorter and less complex than in herbivora, an obvious consequence of the more easy digestibility of the food on which they subsist. In carnivora the cæcum is small, while in herbivora it is remarkable for its length and capacity. In the horse it measures thirty, and in the beaver twenty-four, inches.

In herbivora the stomach is generally complex in its structure, and large in its capacity, so as to be suited for the reception and digestion of a species of food which within a great volume contains little nutriment. It is in ruminants that this complexity of structure is most remarkable.

The transition from the single stomach of carnivora to the quadruple organ of ruminants, is remarkable.

In the solidungula (the horse, ass, &c.) the stomach, though simple, is distinguished by the different structure of different parts of it. In the pachyderms it has peculiar appendages, or sack-like dilatations. In several of the rodents, such as the hamsters and water-rats, it consists of two parts, in the great kangaroo of three, and in the sloth of four. It is, however, in the ruminants that this organ presents the most curious complexity of form.

721. **Ruminants** in general have in the alimentary apparatus four cavities or enlargements, which have received the name of stomachs, the food being first received into one or more of them with little or no previous mastication, where it undergoes the first process of digestion. It is then ejected through the œsophagus, and brought back to the mouth, where it is well masticated and triturated; and, being reduced by impregnation with saliva to a semi-liquid state, it undergoes a second deglutition, and is passed into the other stomachs, where it is brought under the operation of the gastric juice, and then sent through the intestines, as in man.

Rumination is the name given to this part of the digestive process, which consists in ejecting the imperfectly masticated food from the first stomach, and, after mastication, transferring it to the succeeding stomachs.

722. **The Paunch,** sometimes called the *rumen*—a Latin word of like signification—is the first stomach into which the food is received, and is the largest cavity of the digestive apparatus. Its internal surface is lined with a thick epithelium, and, like the skin, is papillary in its structure.

It occupies a large space on the left side of the abdomen. In this compartment the food is submitted to a sort of maceration, produced by its admixture with the saliva.

723. **The Reticulum,** or second stomach, is much smaller, and is in communication with the paunch. It is distinguished by the honeycomb structure and denticulated folds of its lining membrane.

724. **The Manyplies, Omasum,** or third stomach, has a lining consisting of deep longitudinal folds of the mucous membrane, arranged side by side like the leaves of a book.

725. **The Rennet, or Abomasum,** as the fourth stomach is called, has an elongated form, as if it were merely an enlarged part of the intestine. The mucous membrane which lines it is soft. The food having been softened by maceration in the first two stomachs, is, after a certain interval, returned through the œsophagus to the mouth, where it is again masticated ; after which it descends through the œsophagus into the third stomach, and thence by a narrow opening into the fourth.

The first and second stomachs may be considered as diverticula of the cardiac portions of the true stomach. The canal by which they communicate with the œsophagus, called the *œsophageal groove*, admits of being closed and formed into a tube, through which the food passes onwards to the third stomach, after rumination, without entering the first or second.

The stomachs of a sheep are shown in fig. 388, and also in section in fig. 389.

726. It appears that the imperfectly masticated parts of solid food first swallowed pass into the first and second stomachs. All liquid and semi-liquid food, when swallowed, passes directly to the third, and thence to the fourth or true stomach, which alone secretes the gastric juice. This curious circumstance has been explained upon merely mechanical principles by M. Flourens. It has resulted from the experimental researches of that eminent physiologist, that these phenomena are effects of the structure of the œsophageal groove. That apparatus consists of a membranous tube, leading from the œsophagus to the third stomach. The side of this tube is slit open longitudinally, but the edges of this opening remain united, except when opened by some adequate mechanical force. Liquid or semi-liquid aliment descending through the œsophagus does not exert a pressure of sufficient force to open this slit, and it consequently passes directly from the œsophagus to the third stomach. Hence all liquid food first swallowed by the animal passes directly to the third stomach without entering the first or second. The food ejected in rumination, being masticated and triturated in the mouth, and impregnated with saliva and thus reduced to a semi-liquid state, also passes along the œsophageal tube without opening the slit, or passing into the first or second stomachs. It is otherwise, however, with the solid and imperfectly masticated food which is first swallowed by the animal. This, descending from the œsophagus in gross masses, forces open the slit in the œsophageal tube in passing through it, and thus falls into the first and second stomachs.

The regurgitation of the food from the first and second stomachs to the mouth, for the purpose of rumination, has been generally ascribed to the contractile action of the second stomach. It appears, however, from the

researches of M. Flourens, that this contractile action is also exercised by the membrane of the first stomach. The food in these two cavities is by this mechanical force pressed through the slit-like opening in the œso-

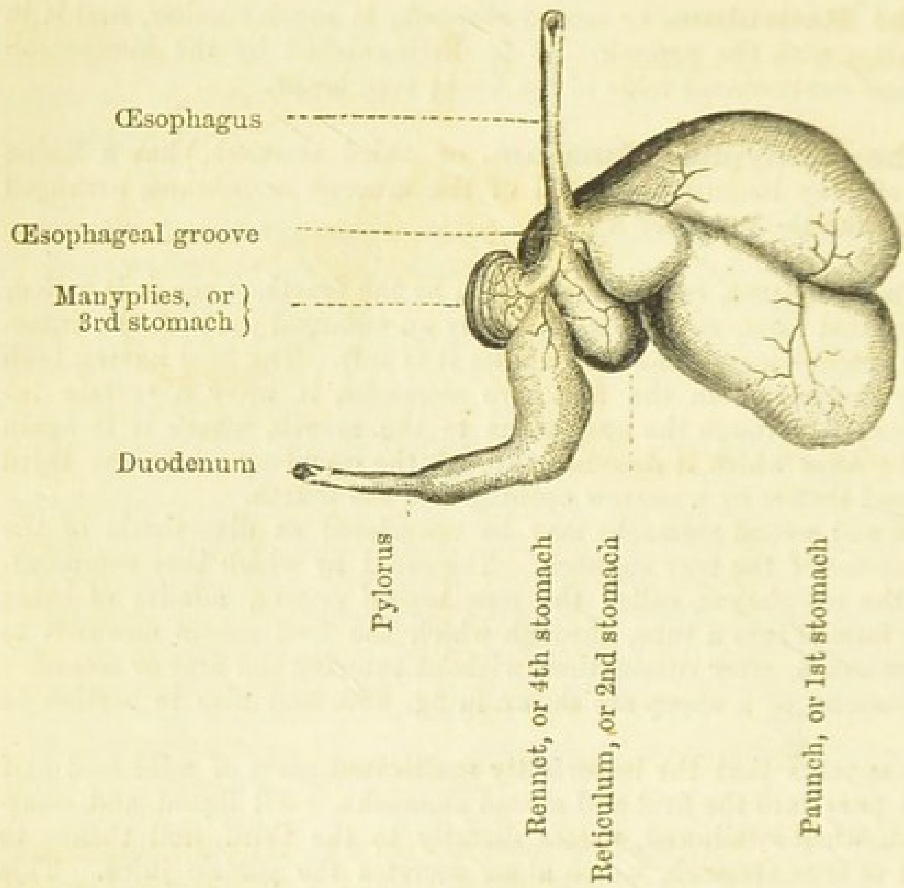


Fig. 388.

STOMACHS OF A SHEEP.

phageal canal, the contractile action of which presses it in pellets or balls towards the œsophagus, which, in its turn exercising a similar contractile force, presses these pellets onwards to the mouth, where the food is, by mastication and intermixture with saliva, brought to a semi-liquid state. It is swallowed, and, as already observed, passes through the œsophageal canal, without opening the slit, into the third stomach.*

In cetacea, the complex structure is found, as well in those which feed on animal as in those which subsist on vegetable food. In the latter, the stomach has several compartments; and in the former it has five, and often more, divisions. During the early part of life herbivora necessarily live on animal food, since they are supported by the milk of their mother.

* Other authorities affirm that this exclusive division of labour between the several stomachs does not take place. According to them, a part of the liquid and semi-liquid food first swallowed passes into the first and second stomachs through the slit in the groove; and they further maintain that even the ruminated food, when swallowed the second time, falls partly into the first and second stomachs, from which it passes into the others. (See Beclard, Traité de Physiologie, p. 121.) Neither the physiological functions nor the mechanical action of the stomachal apparatus, nor even the course of the food in passing through it, are clearly or satisfactorily made out.

It may then be asked how it happens that the organism—adapted, as we have seen, to the difficult digestion of vegetable food—is also suited during this period of life to that of animal aliment. Nothing can be more

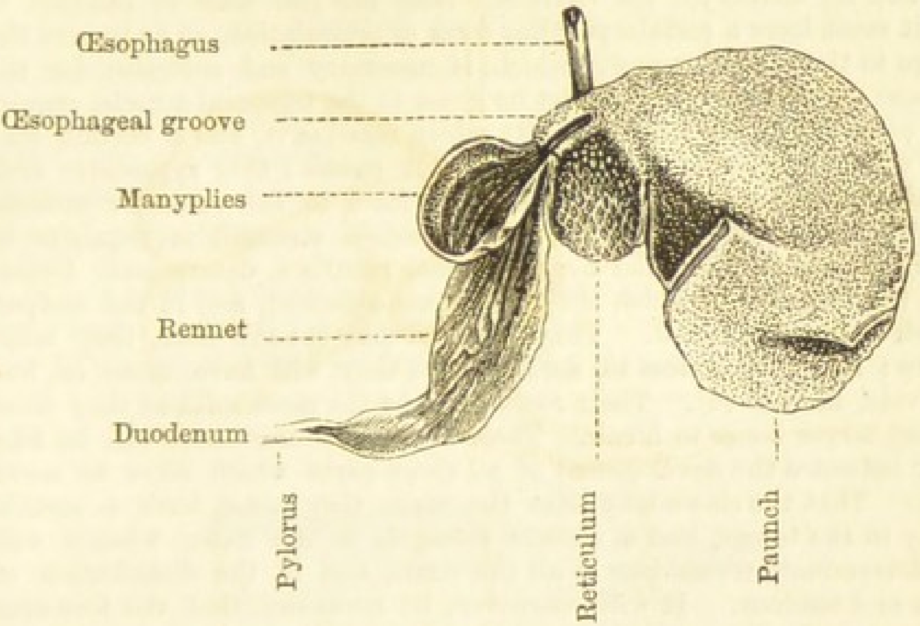


Fig. 389.

STOMACHS OF A SHEEP (Section).

admirable, however, than the contrivance of nature to adapt the structure of the animal to these varying circumstances. Until a certain age, the first stomach, which in the full-grown animal has great capacity, is small; and it is not until the animal arrives at that stage of its growth at which it begins to feed on vegetables that the stomach is enlarged so as to be adapted to the new character of its aliment.

727. The changes in the alimentary canal of certain amphibia, such as the frog, are still more remarkable.

The amphibia in the larva state have an internal canal of great length, and during that time they feed principally on vegetable substances. At a later period, when the character of their aliment is changed, the intestine becomes short.

728. The intimate connection thus existing between the organisation of an animal and the nature of its food, which will appear hereafter in a still more conspicuous manner, has been thus beautifully illustrated by Cuvier.

"Every organised being forms a single and perfect system, the parts of which mutually correspond, and concur in the same definitive operation by reciprocal reaction. None of these parts can change without the whole changing; and, consequently, each of them considered separately indicates all the others. Thus, if the intestines of an animal are organised to digest raw flesh alone, it follows that its jaws must be

constructed to devour a prey, its claws to seize and tear it, its teeth to cut and divide it, the whole structure of the organs of motion such as to pursue and catch it, and its perceptive organs to discern it at a distance. Nature must have placed in its brain the instructive organs to prompt it to conceal itself, and lay snares for its victims. That the jaw may be enabled to seize, it must have a certain peculiar form of articulation, so as to give the leverage to the muscular power which is necessary and sufficient for the resistance; a certain volume must be given to the temporal muscle, requiring an equivalent extent in the cavity which receives it, and a certain convexity of the zygomatic arch under which it passes: this zygomatic arch must also possess a certain strength to give force to the masseter muscle. That an animal may carry off his prey, a certain strength is requisite in the muscles which raise the head; whence results a determinate formation in the vertebræ to which the muscles are attached, and in the occiput in which they are inserted. That the teeth may cut the flesh, they must be sharp; and more or less so, according as they will have, more or less exclusively, flesh to cut. Their roots must be the more solid as they have more and larger bones to break. These several circumstances will in like manner influence the development of all those parts which serve to move the jaw. That the claws may seize the prey, they must have a certain mobility in the talons, and a certain strength in the nails, whence will result determinate formations in all the claws, and in the distribution of muscles and tendons. It will, moreover, be necessary that the fore-arm have a certain facility of turning, whence again will result a determinate formation of the bones which compose it; but the bone of the fore-arm articulating in the shoulder-bone, cannot change its structure without this latter also being modified. In a word, the formation of the tooth bespeaks the structure of the articulation of the jaw; and that of the scapula, the structure of the claws; just as the equation of a curve involves all its properties; and, in taking each property separately as the basis of a particular equation, we should find again both the ordinary equation and all the other peculiar properties. So the claw, the scapula, the articulation of the jaw, the thigh-bone, and all other bones separately considered, require the peculiar tooth, or the tooth requires them reciprocally; and, thus beginning with any one, he who possesses a knowledge of the laws of organic economy would detect the whole animal. We see, for instance, very plainly, that hoofed animals must be herbivorous, since they have no means of seizing upon their prey; we see, also, that having no other use for their fore-feet, than to support their bodies, they have no occasion for so powerfully framed a shoulder; whence we may account for the absence of the clavicle and the acromion, and the straightness of the scapula. Not having any occasion to turn the fore-leg, their radius will be solidly united to the ulna; or, at least, articulated by a hinge-joint, and not by ball and socket, as with the humerus. Their herbaceous diet will require teeth with a broad surface to crush seeds and herbs. This breadth must be irregular, and for this reason the enamel parts must be alternate with the osseous parts. This sort of surface compelling horizontal motion for triturating the food, the articulation of the jaw cannot form a hinge so close as in carnivorous animals. It must be flattened, and must correspond with the facing of the temporal bones. The temporal cavity, which will only contain a very small muscle, will be small and shallow."

729. **The Digestive Apparatus of Birds** is similar to that of

mammifers, with modifications, nevertheless, adapted to the varying habits of the different families of this class. The regimen of birds is very various : some are granivorous, some insectivorous, some piscivorous, and some carnivorous, while some subsist upon mixed food, animal and vegetable. Thus granivorous birds are often also insectivorous or piscivorous.

Birds not being furnished with a dentary apparatus, the office of mastication is transferred from the mouth to the internal part of the digestive canal. The tongue sometimes serves as an instrument of prehension as well as of deglutition.

A view of this organ with its appendages is given in fig. 390, where *l* is the tongue, *h* the hyoid bones, *m* the muscles which move them, *p* the pharynx, *g* the glottis, *t* the trachea, and *e* the œsophagus.

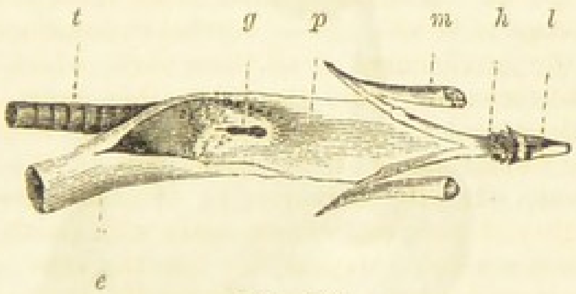


Fig. 390.

TONGUE OF A BIRD, WITH ITS APPENDAGES.

The lingual bones, on which the tongue is supported, are continued backwards in the form of two horns, which at the back of the head are turned upwards. To these horns are attached the muscles which move the tongue, and which are fixed in the lower jaw. By the action of these the tongue is darted out of the mouth with extreme velocity, and sometimes to a considerable distance,—especially with insectivorous birds, such, for example, as the woodpecker. In some species which bruise the food in the mouth, such as the parroquet, the tongue is thick and fleshy. In granivorous birds it is dry, triangular, and bristled at its base with small cartilaginous points. In certain insectivora (fig. 391), its extremity is armed with hooks, and is serrated or notched.

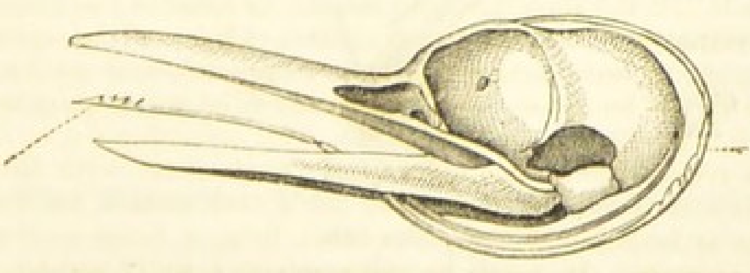


Fig. 391.

HEAD AND TONGUE OF THE WOODPECKER.

The salivary glands are placed under the tongue, and consist of small

masses of rounded follicles. The saliva secreted by them is generally thick, and sometimes glutinous.

730. **The Digestive Apparatus of Birds** will be more clearly understood by reference to fig. 392, which represents that of the common domestic fowl.

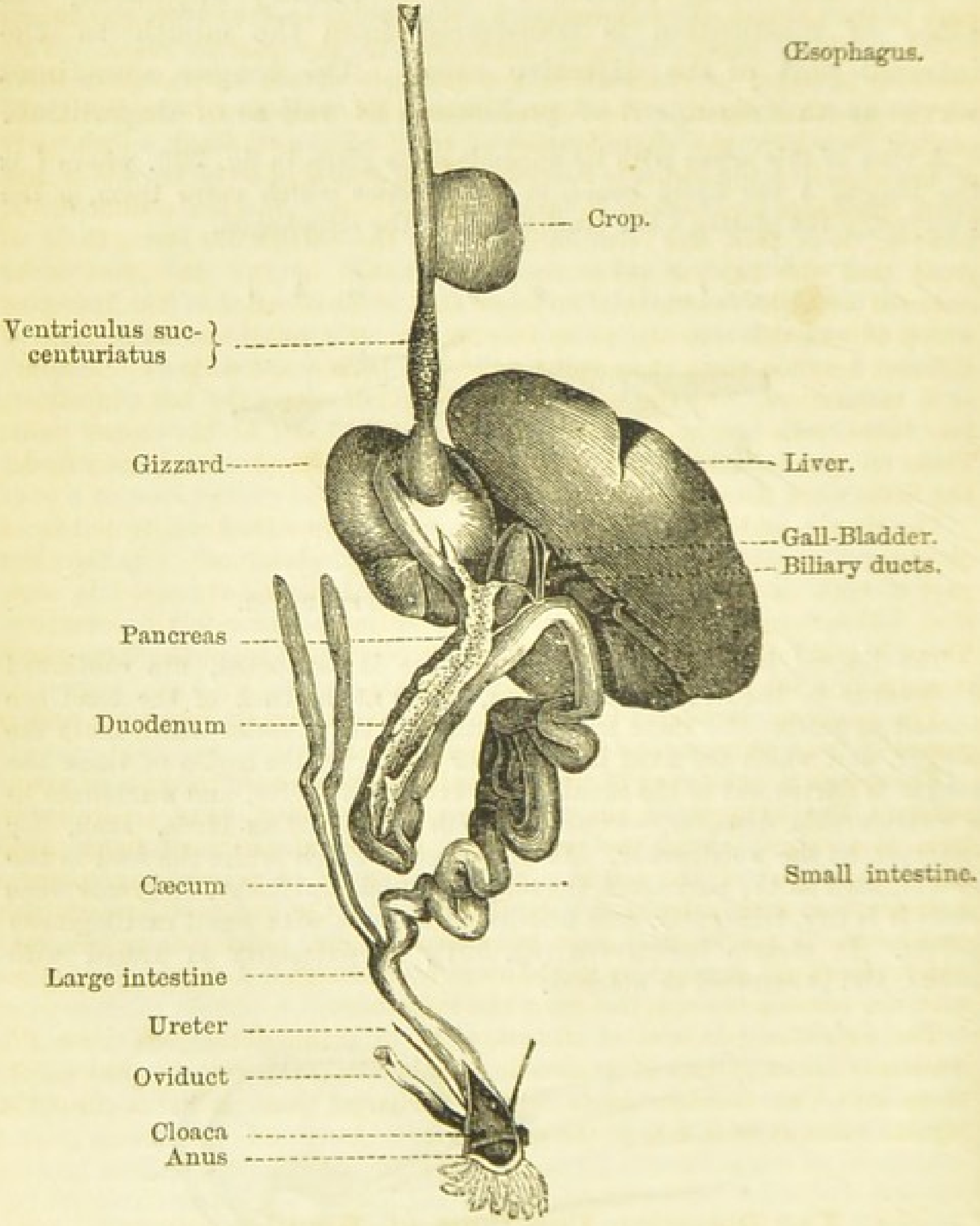


Fig. 392.

DIGESTIVE APPARATUS OF THE DOMESTIC FOWL (Edwards).

The *velum palati*, which in mammifers intervenes between the mouth and the pharynx, is wanting. The œsophagus at the lower part of the neck enters the first stomach, called the *crop*, which is an enlarged pouch

enclosed by membranous walls, the form and magnitude of which differ in different species. In this first cavity the food remains for a certain time.

The *crop* is most developed in granivorous birds, less so in birds of prey, and is altogether absent in the ostrich and most piscivorous birds. Immediately below the crop there is a contraction of the canal, followed by the dilatation called the ventriculus succenturiatus.

Although this enlargement is not considerable, it plays an important part in the phenomena of digestion, its sides being covered with glandulous follicles which secrete a juice analogous to the gastric juice. This ventricle is larger in birds which are destitute of the crop than in those which have that organ. This second stomach is succeeded by a third, the *gizzard*, in which the chymification of the food is completed. This part of the digestive apparatus is furnished with a muscular tunic, which has great thickness and power in granivorous birds. In carnivorous birds, however, it is thin and membranous. In the ostrich its strength is so great that the hardest substances are crushed by it. It seems to be endowed with the functions of an apparatus of mastication. The intestine which follows this consists, as in mammifers, of a small and large tube of different lengths, the former being much the longer and coiled up in folds, as in mammifers. At the point where the small enters the large intestine, two tubes, called cæcums, enter it, which are closed at the upper ends. These are generally long and large in granivorous and omnivorous birds, but little more than rudimentary in birds of prey.

The thorax and the abdomen are not, as in mammifers, separated by a diaphragm muscle ; and the liver, which is very voluminous, fills the chief part of both cavities. It is divided into two lobes nearly equal in size, from which issue two ducts, which, after uniting, open into the intestine. There is generally a gall-bladder which receives a portion of the bile, which it pours into the intestine by a separate canal.

The pancreas is lodged in the first fold of the small intestine, and is generally long, narrow, and more or less divided.

The spleen is small, and its uses are as little known as in the case of mammifers. The kidneys, on the contrary, are very voluminous, irregular in form, and lodged behind the peritoneum in several cavities formed along the superior part of the pelvis. They do not, as in mammifers, possess a distinct cortical substance. In that part of the great intestine which corresponds to the rectum, there is an enlargement, called the cloaca, into which the liquid secreted by the kidneys is discharged, and where it mixes with the excrements expelled from the intestines.

The nutritive products of digestion, as in mammifers, pass from the intestines into a system of lymphatic vessels connected with it, which converge into two thoracic ducts which discharge their contents into the jugular veins at each side of the neck.

731. **The Digestive Functions of Reptiles** compared with those of former classes are languid, and the blood is cold, varying in its temperature with that of the surrounding medium. These animals are capable of bearing abstinence from food for long periods of time. Their rare secretions, low temperature, and scaly and impermeable envelope, render their losses by

cutaneous evaporation very inconsiderable, circumstances which explain their power of bearing the want of drink.

Reptiles have generally a mouth of great capacity, with teeth in the jaws, and even in the vault of the palate. Their teeth, unlike those of mammifers, are not alveolar, but form part of the bone of the jaw to which they are attached. Some reptiles are destitute of teeth, and instead of them, are supplied with horny jaws, like those of birds. Tortoises are examples of this class. Reptiles in general are supplied with a series of salivary glands surrounding the jaws. The venomous glands with which some reptiles are supplied, have been already described. The stomach, which is generally simple, is variously formed in different species. The intestines are generally short, the liver voluminous, and the pancreas in its usual place. The large intestine differs but little from the small, and terminates in a cloaca, as in birds. The digestive apparatus is surrounded with lymphatic and lacteal vessels, which transport the produce of digestion into the blood.

732. **Fishes** in general are very voracious, and, with a few exceptions, feed indiscriminately on all the smaller animals that come within their reach. Some species are without teeth, but most sorts have several rows of them, and most commonly they are not only ranged as usual round the jaws, but planted in the bones of the palate, and even in those of the pharynx as far as the embouchure of the œsophagus. They differ in their anatomical character from the teeth of mammifers, not being planted in sockets, but forming part of the bones from which they project. They nevertheless fall, and are replaced by new ones, but the process more resembles the fall and renewal of the deer's horns than the change of teeth in mammifers.

The form of the teeth of fishes varies much. They are sometimes delicate, close, and sharp, resembling the pile of velvet, sometimes strong and hooked, sometimes formed of sharp blades, and sometimes of rounded tubercles; but in general they merely serve for the retention or fraction of the prey, and not for mastication properly so called.

Some species of fish feed exclusively upon the blood and juice which they suck from the bodies of other animals. The mouth in this case is formed of a series of concentrical cartilaginous rings, which replace the lips and jaws, while their surface, being studded with bony points, supply the place of teeth. The tongue moves inwards and outwards through this central orifice, and being also furnished at its point with teeth, plays the part of a piston, and, in fact, converts this curiously constructed mouth into a cupping-glass,—the teeth upon the tongue, aided by those surrounding the borders of the mouth, replacing the lancets. The lamprey presents an example of this class of fish.

The mouths of fishes are not supplied with any salivary gland. The œsophagus is short, and the stomach and intestine vary in different species, as well in form as in dimensions. The liver is generally large, and of soft tissue. The pancreas is always absent, but sometimes replaced by cæcums of a peculiar tissue established round the pylorus. The place of the anus

varies, being sometimes found under the throat, and sometimes at the base of the tail. The kidneys are extremely voluminous, and extend throughout the entire length of the abdomen on each side of the vertebral column. Their excretory ducts leading to a species of bladder, whose external orifice is placed immediately behind those of the anus and the reproducing organs.

The digestion seems to be performed with great rapidity, the chyle being absorbed by numerous lymphatics which lead by several trunks into the venous system near the heart.

733. **The Digestive Apparatus of Invertebrates** varies much in its form and arrangement according to the varying habits and nutriment of the animal, and according to the medium in which it lives.

734. **Insects** vary in their nutriment. Some feed upon the juices of plants, some upon those of animals, while others feed upon the solid parts of the one and the other. Their several instruments of prehension, and more especially the structure of the mouth, have corresponding differences.

With insects which grind their food, such as the scarabei, the may-bug, the blatta, and the grasshopper, the mouth is formed in front by an

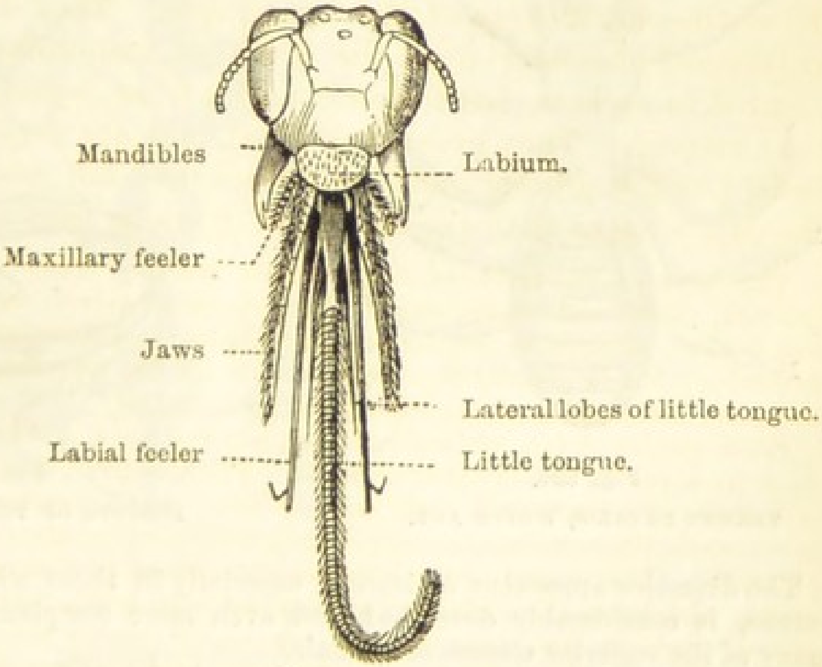


Fig. 393.

upper lip, and is supplied on each side by a large moveable cutting instrument, called a mandible, which serves to divide the food. Behind these are the jaws, each of which has a plate, or cylinder, more or less hard, furnished with small teeth or hairs, and is supplied on its external side with two small, projecting, jointed pieces, called maxillary palpi, or feelers.

Behind these is a pair of appendages whose base is supported by a horny piece in the middle, called the chin. These appendages constitute the languet, or tongue. There is also a pair of articulated filaments, called labial palpi. These parts, however, vary in different species, according to the nature and consistency of the food. The palpi serve principally to seize the food and hold it up between the mandibles, which cut it.

As an example of the mechanism of the head and its appendages, that of the bee may be given. The chief part of the mouth consists of the *tongue*, the *jaws*, the *lips*, and the *throat*, or œsophagus.

The jaws are each double, separated by a vertical division. Each pair opens, therefore, with a horizontal instead of a vertical movement, like the human jaws. The upper jaws are called *mandibles*, and the lower *maxillæ*. The upper lip is called the *labrum*, and the lower the *labium*. The mouth is also supplied with two pairs of special organs, called *palpi* or feelers, one pair attached to the lower lip, and called *labipalpi*, and the other to the lower jaw, and called *maxipalpi*.

In fig. 393 is given a magnified view of the buccal apparatus of the wild bee (*anthophora retusa*), the parts being indicated.

In fig. 394 is represented the *termes fatalis*, or white ant, on a magnified scale, showing the powerful mandibles in the front of the head; and in fig. 395 is a separate view, also on a magnified scale, of the forceps,—a complex instrument of prehension of the same insect.

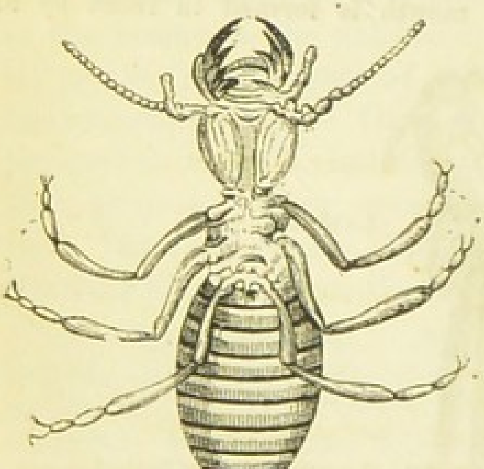


Fig. 394.
TERMES FATALIS, WHITE ANT.

Fig. 395.
FORCEPS OF TERMES FATALIS.

The digestive apparatus of insects, especially in those which are herbivorous, is considerably developed, and even more complex than that of many of the superior classes of animals.

Its general form and arrangement is shown in fig. 396.

Three stomachs intervene between the œsophagus and the intestine,—the crop, the gizzard, and the chylific or true stomach.

The alimentary canal is sometimes straight, and of nearly uniform

calibre throughout its whole length, but is more frequently tortuous and various in diameter, presenting successive enlargements and contractions, such as are represented in fig. 396.

Fig. 396.
DIGESTIVE APPARATUS OF INSECTS (Edwards).

The sides of the second stomach, or gizzard, which are muscular, are supplied with horny parts that triturate the food; the third, or true stomach, called the chylific ventricle, is of soft and delicate texture. In carnivorous insects the alimentary canal is short, while in those which are nourished on vegetable substances it is very long. The food of the insect is impregnated with saliva secreted in a number of floating tubes, termi-

nating sometimes by a sort of utricle, and communicating with the pharynx by excretory canals. The gastric juice is secreted by a multitude of villosities with which the chylific stomach is furnished. The functions of the latter are performed by a system of long and delicate tubes which float within the abdomen communicating with the chylific stomach.

735. **Mollusca** are often provided with largely-developed digestive apparatus, supplied with salivary glands and a voluminous liver. In general, the extremity of the intestinal tube, instead of terminating in a remote part of the body, returns to some point not distant from the mouth, which forms its embouchure of discharge. Some mollusca, including cephalopods, have masticating organs or mandibles.

736. **In Radiata** there is sometimes, as in the holothuria and echinoidea, &c., an intestinal canal open at both ends. The embouchures are at opposite extremities of the body in the holothuria, but in the echinoidea the mouth is in the middle of the under surface, and the anus of the upper. In the asteroids there is merely a stomach with cæcal appendages, without any intestinal canal.

CHAPTER X.

ASSIMILATION—SECRETION—THE SKIN—ANIMAL HEAT.

737. **Assimilation** is the name given by physiologists to the process by which new matter is deposited in the living organs, assuming there a suitable arrangement, and acquiring the vitality with which the parts to which it becomes united are already endowed.

738. **Return of the Lymph.**—The manner in which the molecules of nutrition pass through the coats of the sanguiferous vessels to the surrounding tissues is unknown. It is considered by some physiologists that the red globules of the blood are gradually dissolved in the serum, so as to form the plasma which transudes through the coats of the vessels, and that this liquid, after having imparted to the tissues the principles suited to their maintenance, being thereby converted into lymph (24), is taken up by the lymphatics, as already explained (516), and is by them re-conducted to the circulating apparatus, where it is re-combined with the blood ; and, being again charged with the nutritive principles, re-commences its course through the organism.

739. **Unexplained Phenomena.**—But when this supposition is accepted, much still remains to be explained in this curious body of organic phenomena. What is the principle by which each class of organ derives its power of selection among the components of the passing current, by which it seizes precisely that particular aliment which is capable of combining with its own substance and rejects all the others ? How does it come to pass that an organ formed of fibrine selects the fibrine only, and another composed chiefly of albumen selects albumen only, and another, in which calcareous salts prevail, will seize by preference a supply of those particular components of the blood ? And, how does it happen that the specific molecules thus selected by the organs severally array themselves in the peculiar way which is proper to form the texture of the particular tissues, and always unerringly fall into the same

arrangement? And how, in fine, are these inert particles vitalised by mere juxtaposition with particles already endowed with the properties of life? These are questions so closely connected with the essential principle of life itself, as to lie upon the extreme limits of physiology, and to present few probabilities of speedy solution. It may, nevertheless, be useful to observe in reference to them, that in all animals provided with a fully developed nervous system, that apparatus exercises a marked influence on this class of phenomena.*

740. **Growth.**—It is during the early period of life that the function of assimilation is exercised with its greatest energy. Growth is a phenomenon common to all organised beings. Its continuance is generally limited to a certain period of life, which is more prolonged as the animals are placed lower in the scale of organisation, so that with some of the lowest it has no other limit than life itself. With those of the higher organisation its period consists of the third or fourth part of the entire duration of life.

Growth is applicable to the organs separately, as well as to the whole body, their increase not being necessarily proportional to, or concomitant with, that of the latter. There are certain parts, such for example as the thymus, whose growth is exclusively intrauterine.† Of others, such as the bones, the limit of growth coincides with the adult age; and of others, such as hair and nails, the growth continues through life.

741. **Reproduction of Mutilated Parts.**—The power of assimilation is not merely limited to the wear and tear of the tissues produced by the normal action of the vital functions. It extends, also, to the reproduction of parts destroyed by violent, accidental, and abnormal causes. It is thus that the skin is cicatrised after a wound, and large patches of that membrane destroyed by burns are reproduced. Of all the tissues, the bones, though apparently the least likely to be reproduced by mere growth, are precisely those most completely regenerated when partially, or even wholly destroyed. The fractured

* Milne Edwards, Zoologie, p. 114.

† The thymus is a gland situated in the lower part of the neck and upper part of the thorax, close behind the sternum. According to Quain it does not attain its full growth till the second year, but according to French physiologists it has its greatest development at the moment of birth, and then disappears, being probably subordinate to the function of nutrition during the period of lactation. Beclard, Phys., p. 415. Milne Edwards, Zoologie, p. 114.

extremities of a bone, when brought together, are soon consolidated and knit by the growth of a new bony substance between them, and thus re-union even takes place under circumstances so unfavourable as to render it impossible to avoid leaving a certain space between the fractured surfaces. In all such cases, the materials out of which the new bony matter is formed, are supplied by the plasma proceeding from the blood-vessels, which permeate the bone-cells, the periosteum, the surrounding muscles, and their tissues.

742. **Restoration of Bones.**—It often occurs that the fragments of bones, much more considerable in magnitude, are supplied by this process of abnormal growth. When, by disease, large portions of bones have been lost, they are replaced by osseous matter of new production. These parts generally differ more or less in their form from those which they have replaced, but their structure is essentially the same, and they fulfil the same functions.

It results from the researches of Heine, that this power of regeneration extends not alone to the pieces cut out of large bones, but in certain cases to the replacement of entire bones. That physiologist has shown that when the separated pieces of a large bone, from which a part has been cut out, are not reunited by true bony matter, but by false articulations consisting only of fibrous adherent matter, the failure is due, not to nature, which has provided a perfectly efficient process for the repair of the injury, but to the difficulty of maintaining the parts perfectly immoveable during the process of consolidation. When a piece has been removed from the long bone of a member in which a similar bone is found in juxtaposition —as is the case of the bones of the leg (103)—or even when one of the two bones has been altogether extracted, the companion bone (such, for example, as the tibia) maintains the parts in their normal position, thus playing the part of a natural splint, and the bone partially or wholly extracted is reproduced.

The fibula of a dog wholly extracted was thus reproduced, as were also ribs and other parts of the thoracic cage.

743. **Crystalline Humour.**—Among the parts capable of this reproduction, one of the most unexpected is the crystalline humour of the eye. Numerous and well ascertained facts prove that, not only in the case of the lower animals, but in the human organism, the crystalline will be restored by growth, provided the capsule containing the humour be not destroyed. The capsule in this process is the organ of secretion.

744. **Cartilages.**—In the other tissues subject to injury or destruction by accident or disease, the cartilages are very imperfectly reproduced, and the muscles not at all.

745. **The Brain and Nerves.**—The parts of the cerebral matter removed by accident or disease are not replaced by growth. Nerves divided may be re-united by cicatrisation; and may, in a greater or less degree, recover their functions, whether sensitive or motor. But if a piece be cut out of the nerve, half an inch or upwards in length, no re-union will be possible. The two stumps will then cicatrise separately, but will not re-unite, and the function of the nerve will be irrecoverably lost.

746. **Blood-vessels.**—That the circulating vessels, after accidental separation, may be re-united so as to recover their functions, is proved by the well-known operation, in which the nose or ears, after having been cut off, are re-attached with complete recovery of their vitality. In such cases, new circulating vessels are formed between the divided parts, by which the blood is conducted to the vascular organs of the part re-attached. An autoplastic operation, by which a part destroyed is formed out of the tissues taken from another part of the body of the mutilated patient, and a new system of circulating vessels produced by factitious growth, is presented in the case in which a nose is formed out of flesh drawn from the forehead.

747. **Regeneration in Inferior Animals** is, however, displayed in the most conspicuous manner. Thus the tail of a lizard cut off is soon reproduced, notwithstanding its somewhat complex structure; and it is well known that if a leg of a spider or crab be broken off, another similar and equally efficient member will grow from the stump. Experiments made on salamanders and lizards have shown a still more extraordinary power of reproduction. The eyes and part of the head of these animals being destroyed, are replaced. Earthworms and many other annelida have the power of reproducing in the same way the greatest part of their bodies; and in the case of hydras or fresh-water polyps (fig. 386), even a small fragment of the body is sufficient to reproduce the whole.

748. **The Plastic and Respiratory Constituents in Food** (637) should correspond with the excretions, so as to maintain in the system these elements in due proportion. According to this view, the food should contain one part of plastic to four of respiratory matter. Such a proportion corresponds also to the composition of woman's milk, the exclusive nourishment of the young infant; that liquid containing ten parts of caseine, the nitro-

genised constituent, to forty of sugar, fat or butter, the non-nitrogenised constituent.

749. **Liebig's Table.**—In relation to this point, the following table, taken from M. Liebig may be consulted with advantage.

Composition of Different Aliments.	Nitrogenised Principles (Albuminous Matters).	Non-Nitrogenised Principles (Fat, Sugar, or Fecula).
Woman's milk	10	40
Cow's milk	10	30
Lentils	10	21
Beans	10	22
Peas	10	23
Mutton fat	10	27
Pork fat	10	30
Beef	10	17
Wheat	10	46
Oats	10	50
Rye	10	50
Barley	10	57
Potatoes	10	86
Rice	10	123
Buckwheat	10	130

750. **Salt.**—Among the condiments which man uses with his food, common salt, or the chloride of sodium, as chemists call it, holds the first rank. A man consumes in his aliments and drink about eight grains of this substance per day, and from a quarter to half an ounce of it is contained in cooked food. In the composition of the human body there are from eight to twelve ounces of the chloride of sodium, or other equivalent salts; and it must not be forgotten that among the salts of the blood the chloride of sodium holds the first place. Its influence is essential to the constitution of this liquid by maintaining its alkaline quality and its coagulability. A great number of organic compounds which, at the temperature of the body, do not combine with oxygen, acquire this property when they are placed in contact with alkalis. Sugar, for example, decomposes metallic oxydes at common temperatures, when in contact with alkalis. The alkaline salts of the blood, and the chloride of sodium in particular, favour and augment the combustibility of the organic elements of that fluid by the presence of oxygen.*

* In blood the alkaline chloride in the plasma is chiefly chloride of sodium, whereas the corpuscles contain chiefly chloride of potassium, in this agreeing with the muscular tissue. Recent inquiries would seem to show that a certain amount of potash salts in the body is essential to health; and probably potatoes, milk, and fresh vegetables, owe their efficacy as anti-scorbutic diet, in some measure, to the potash which they contain.

751. **Water.**—The necessity of an abundant supply of water in the human regimen is proved by the fact already indicated, that 77 parts in 100 of the substance of the body consist of that liquid. Water is the menstruum of all the absorptions, secretions, exhalations, and various chemical operations which are accomplished in the organism. It confers upon the blood that degree of fluidity which is indispensable to circulation, and maintains the different tissues in the state of suppleness and softness necessary to the fulfilment of their functions. Animal life is not possible, unless the tissues be continually impregnated with liquid matter. All that is solid and dry is inert and lifeless. Water dissolves and brings into juxtaposition the substances intended to react one upon the other. It is, moreover, in the different operations of organic chemistry, sometimes produced and sometimes decomposed, its constituents entering into and issuing from innumerable organic combinations. It has also many physical and mechanical uses in the economy. Being sensibly incompressible, it maintains the volume and situation of the parts, and resists all causes of their compression.

The water contained in the body is continually renewed by drink, and continually evacuated by the various organs of secretion. The quantity daily taken into the body is considerable. That which escapes by exhalation and secretion is not altogether represented by what is drunk and what enters into the composition of food. If we sum up the quantity of water given out by the human body in twenty-four hours by all the agencies of secretion, excretion, and evaporation, it will be found that this quantity is greater than the quantity introduced in food and drink. The water which issues in these various ways may be estimated at about five and a-half pounds, or a little more than two quarts, while the quantity taken in drink and involved in the composition of food does not much exceed three pints. This excess contained in the exhalations and secretions is partly due to the absorption of water by the skin, and is also produced by the combination of oxygen and hydrogen in the organism in the various chemical changes which the elements of nutrition undergo. The water formed in the body from the oxygen respired, combined with the hydrogen of the organic principles of the food is, as we shall see, one of the principal sources of animal heat.

The quantity of water which is taken in drink daily is subject to much less variation than it appears to be, and is subject, moreover, to changes, according to the aqueous evacuations. One who observes exclusively, or nearly so, a vegetable diet, drinks much less than others; but it must be considered that the vegetables on which he feeds are impregnated in a much greater degree with water than is animal food. In warm weather the abundance of transpiration and perspiration render it necessary to replace the water expelled, and thus to maintain the blood in its normal state of fluidity. Consequently, during the warm season, the mass of water which traverses the body is considerably augmented. In certain maladies, in which a morbid discharge of water takes place, the quantity

of the fluid taken in the form of food is double, or even triple, the normal consumption.

752. **Absorbing Apparatus of Digestive Canal.**—The body, as we have seen, receives the matter necessary for its repair chiefly by the absorption of the intestinal canal. The structure and form of the coats of the stomach and the smaller intestine are eminently adapted to promote this purpose. The innumerable glands or equivalent organs which are spread over their internal surface, penetrating their structure and communicating with the veins and lymphatics, have been already explained. Their form is not less adapted to promote this absorption.

The internal surface of the stomach of an adult person measures about 100 square inches ; and, taking the average diameter of the small intestine at an inch and a quarter, and its length at twenty feet, the magnitude of its internal surface will be, in round numbers, 1000 square inches, or something more than six square feet. This vast surface, combined with its peculiar structure, will easily explain the celerity with which liquid matter flowing from the stomach through the intestine is transported through the circulation.

753. **Absorption and Exhalation equal.**—Since, after full growth, the body maintains its average weight nearly constant, it follows that the quantity of worn-out matter which it dismisses must be equal to the quantity of new matter which it appropriates. The processes by which this matter is thus dismissed from the organism are exhalation and secretion. Exhalation is little more than a physical process, depending on the greater or lesser permeability of the tissues. Secretion, on the other hand, is a physiological and chemical operation, by which specific substances are eliminated and selected among the constituents of the blood, to be either expelled from the body, as in the discharge of mucus and urine, or to be brought into combination with substances received from without, and thus to serve the purpose of vital action, as in the case of the intestinal juices.

754. **Exhalation.**—The coats of the vascular apparatus are permeable by fluids, and, as a consequence of this, the water, gases, and other compounds of the blood, pass through them ; but the globules, however minute, being solid, are retained. Exhalation takes place as well from the external as from the internal coating of the body. That which is produced upon the external surface, however, must not be confounded with

sweat. Cutaneous exhalation is evaporised, and, issuing from the pores, and not appearing visibly on the skin, is called insensible transpiration. It was computed by Sanctorius, that as much as five-eighths of all the matter expelled from the body escapes in this way.

Of the internal exhalations, one of the most important is that of carbonic acid dismissed from the lungs. This gas is also exhaled from the skin, but in a much smaller proportion. It is computed that the total quantity dismissed in a given time from the entire external surface of the body amounts to no more than the thirty-eighth part of that which is exhaled from the lungs in respiration.

755. **Cutaneous Respiration.**—While the skin exhales carbonic acid it absorbs oxygen, and thus discharges the functions of respiration; but, owing to its very inferior permeability compared with the mucous membrane of the lungs, its effect on the blood is altogether inconsiderable; so that, notwithstanding this respiratory action of the entire tegument of the body, the blood on arriving at the lungs still retains its venous character, and depends mainly for its arterialisation on the more active principle of pulmonary exhalation and absorption.

756. **Disturbances of Exhalation.**—Exhalation takes place through the mucous and serous membranes which line all the internal parts of the organism, with an energy so much the greater than cutaneous exhalation, as these membranes are thinner and more pervious to fluids than the skin. This internal exhalation must, in the normal state of the organism, be in exact equilibrium with the absorption or inhalation. Disturbances in this equilibrium are the cause of specific diseases. If the exhalation be deficient, the fluid which ought to be expelled accumulates, and produces dropsy, which takes different names according to the seat of the disturbance; such as hydrocephalus, or water on the brain; hydrothorax, or water on the chest; ascites, when its seat is in the abdomen; and so on.

757. **Cutaneous Transpiration.**—Although the exhalation of carbonic acid from the skin is, in comparison with the lungs, inconsiderable, the same is not true of cutaneous transpiration.

Without taking into account the exhalation of water in the liquid state, which is only an occasional phenomenon, it is calculated that the average quantity of water expelled from the organism per day is 2·2lbs., or about a quart. The quantity dismissed in pulmonary exhalation in the same time does not exceed a pint.

The cutaneous exhalation of water is subject to great variation, being submitted to very various external influences, among which the thermal and hygrometric states of the air are the principal. The atmosphere is sometimes—but rarely—charged to saturation with humidity. More commonly, it is below the point of saturation, but nearer to or more distant from it within very wide limits. The nearer it is to that point, the less freely does cutaneous transpiration take place, and vice versâ. The humidity of the air is greater in summer than in winter, the elevated temperature at once favouring evaporation and increasing the hygrometric capacity of the atmosphere. Dalton calculated that the average transpiration of vapour —cutaneous and pulmonary—is greater in June than in March in England, in the ratio of 64 to 37.

The disturbance of equilibrium produced by the varying capacity of the air for moisture, when not too extreme or sudden, is compensated by the urinary secretion, which is more abundant when the cutaneous respiration is less free.

758. **The Importance of Cutaneous Respiration** to the maintenance of the vital functions has been demonstrated by experiments on the inferior animals.

The skin of dogs, sheep, rabbits, and horses, being shaven, has been coated with an impermeable varnish, so as completely to suspend cutaneous respiration and transpiration. The animals under such conditions have rarely survived more than a few hours. After death the tissues and organs have been found to be gorged with black blood. Since it is not probable that such a change in the blood could arise from the mere retention of water, which, as just explained, is more or less compensated by the increase of urinary secretion, it may be inferred that in these cases the cause of death is the suspension of the interchange of carbonic acid and oxygen between the air and the skin; or, in a word, the suspension of cutaneous respiration, properly so called. In short, the phenomenon is nothing more or less than slow asphyxia.

The exhalation of carbonic acid by the skin being thirty-eight times less than by the lungs in man, and less in a still greater proportion in animals which have a covering of wool or hair, it follows that its suspension, if continued thirty-eight times as long as the suspension of pulmonary respiration, will produce an equal effect. When pulmonary respiration is suspended, asphyxia is rapid; when cutaneous respiration is suspended, it is much slower, but not less inevitable. By the suspension of pulmonary respiration for three or four minutes in man, life becomes extinct; by the suspension of cutaneous respiration for two or three hours, it is probable that the same result would ensue.

759. **Waterproof Dresses dangerous.**—The injurious and even dangerous consequences attending the use of articles of clothing rendered impervious to water, and therefore also to air, by caoutchouc, will be thus apparent. Such vestments obstruct cutaneous respiration to a very considerable degree; and cases have occurred of individuals having sporting-dresses

prepared in this way whose lives were sacrificed to the experiment.

760. **Pollution of Atmosphere.**—When animals live in the open air, the effect of their respiration on the atmosphere immediately disappears; but it is otherwise when they live under the artificial conditions created in civilised life. In a close and covered habitation, man is shut up in a volume of air of limited dimension. If provision were not made to insure a change of this air, it would in a certain time be rendered incapable of supporting life, by reason of the conversion of an undue proportion of its oxygen into carbonic acid. But, independently of the impurity due to respiration, pulmonary and cutaneous, there are other sources of impurity incidental to transpiration not less serious. The vapour exhaled from the surface of the body, internal as well as external, holds in suspension organic matter, which, impregnating the air confined in a chamber, produces effects far more injurious than those which result from an insufficient proportion of oxygen. This is one of the frequent causes of typhoid maladies and contagious diseases.

761. **Ventilation.**—Taking into account the above and other sources of atmospheric impurities, such as the combustibles used for illumination, it is computed that a supply of 350 cubic feet of fresh and pure air per hour is necessary for the health of each adult inhabitant of a chamber.* It will be apparent that few inhabited rooms fulfil these conditions.

Many bedrooms in which we pass ten hours of the twenty-four are insalubrious from insufficiency of ventilation, and this is especially the case when there is no chimney.

762. **Secretions.**—It is not easy to limit in a rigorous manner the signification of this term. If every humour which exudes from the blood through the coats of the vascular system be admitted to be a secretion, there would not be a single tissue

* It is not necessary to take into this account the combustible used for warming apartments, since, in properly constructed fire-places, the products of combustion pass up the chimney, and the fire, instead of being the cause of impurity, is, or ought to be, a powerful instrument of ventilation. For this reason, rooms during the summer season, when fires are not used, and bedrooms without fires at all seasons, need to be more carefully ventilated. To prevent a down current when no fire is lighted, it is usual to provide a trap or other expedient to close the chimney, in which case the room is nearly deprived of all means of ventilation.

composing the body which would not be a secretory organ, and if all such organs were called glands, the entire body would consist of a mere mass of glands. However useful such general views may be in a scientific point of view, it is necessary to impose narrower limits to the signification of terms.

The blood is the common fountain of all secretions. The parts secreted from it transude through the coats of the blood-vessels, and through the membrane which envelops them, and being diffused upon the external surface of the membrane, are sometimes accumulated in cells, or other suitable reservoirs.

763. **Secreting Organs.**—Since the abundance of the secretion, other things being the same, is proportional to the magnitude of the secreting surface with which the blood is in contact, nature has adopted a series of expedients by which, within a given space, this surface acquires the greatest possible dimension.

These expedients in general consist of giving to it a cellular, saccular, or tubular structure, and diffusing the blood over it in a system of finely-ramified capillary vessels. These are spread in a net-work over all the minute cells, sacs, ampullæ, and tubes. By this means the blood is not only brought into contact with an extensive secreting surface, but its current being retarded in the same proportion as the calibre of the vessels through which it passes is diminished, it is retained for a longer time in contact with that surface, so as to allow the functions of secretion more ample play.

764. **Structure of Secreting Surfaces.**—In every such apparatus, therefore, the reticulation of blood-vessels is first covered by a simple tissue called the *basement membrane*, upon which the cellular, saccular, or tubular structure of the secreting organ is formed, and through which the secretion takes place. The cells, sacs, or tubes, may either project from the secreting surface, or may be formed in it like cavities. In the one case they are analogous to cameo and in the other to intaglio. A theoretical diagram of a membrane of the former class is given in fig. 397, and one of the latter in fig. 398.

In these figures *c* represents the reticulation of blood-vessels, *a* the basement membrane, and *b* the surface of the secreting cells, sacs, or tubes.

The secreting surface may also be increased within a given bulk by giving to the membrane a plaited or fringed form. Thus, *d* may represent a single plait or fold, *e* several such folds having a common opening, and *f* a system with fringed edges. In fig. 398, *g* represents a tubular, and *h* a saccular cell. A cell in which a large tube is coiled up into a ball is shown at *i*. Circular cells with locular sides, formed to augment still more the secreting surface, are shown at *k* and *l*.

Sometimes the tube terminates in a small globular vessel, the surface of which is similarly loculated, and a multitude of these tubes coalesce in

common embouchures, as at *m n o*. Sometimes a number of small

Fig. 397

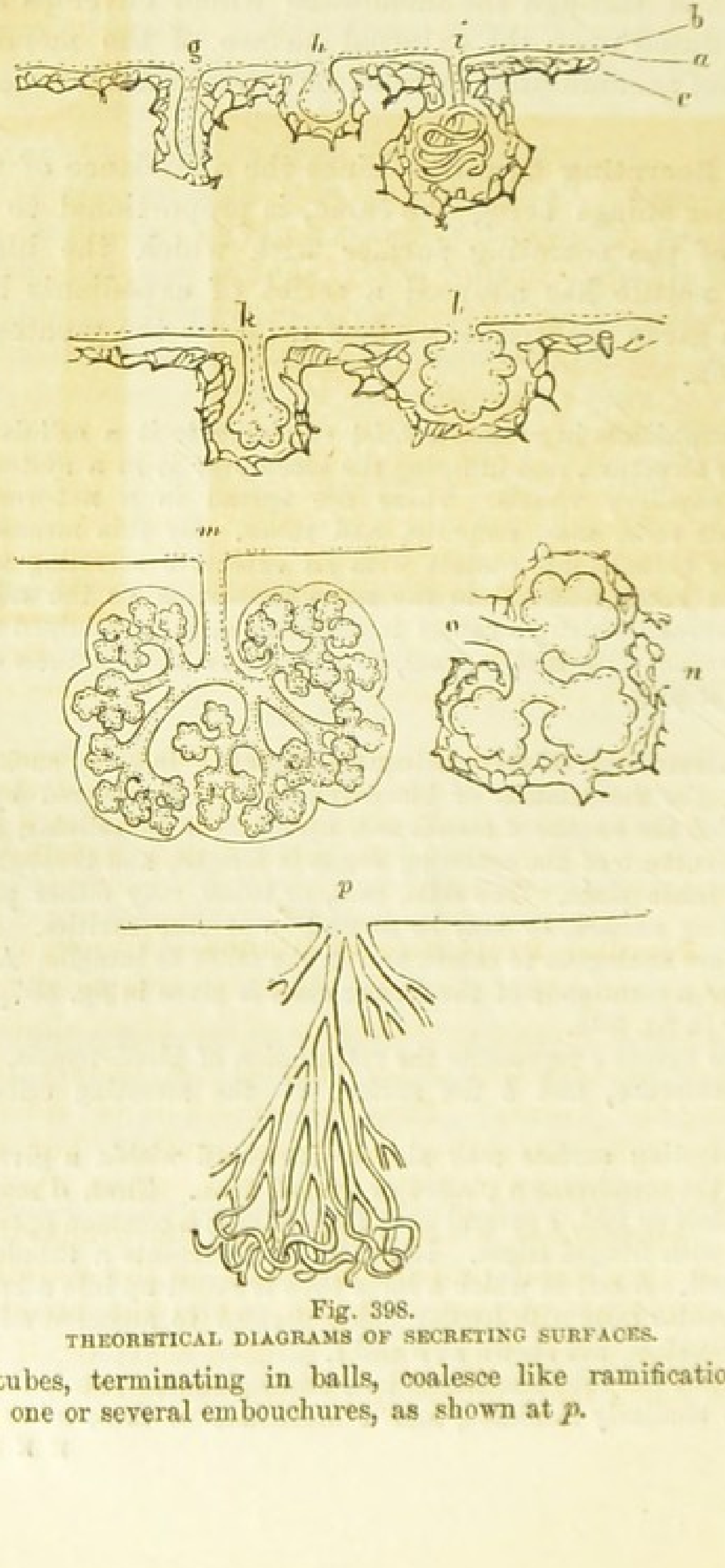


Fig. 398.

THEORETICAL DIAGRAMS OF SECRETING SURFACES.

secreting tubes, terminating in balls, coalesce like ramifications, from a trunk in one or several embouchures, as shown at *p*.

765. **Glands.**—Such in general is the structure of the apparatus of secretion, which takes a variety of names, such as *simple glands* (*g h i*), *multi-locular crypts* (*k l*), *racemose* or *vesicular glands* (*m*) *compound tubular glands* (*p*), and so on. The parotid, one of the chief salivary glands (fig. 399), is an example of a compound racemose gland, and the kidneys (fig. 400) of a compound tubular gland.

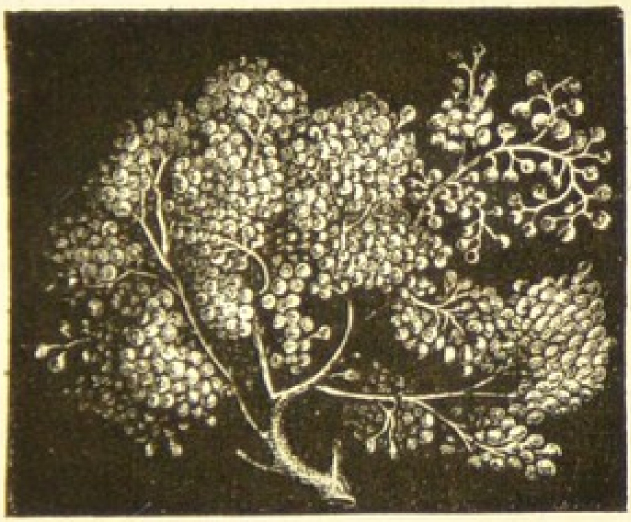


Fig. 399.
PAROTID GLAND (Edwards).

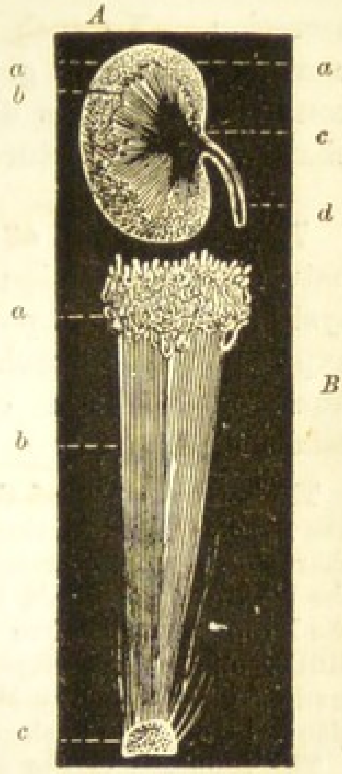


Fig. 400.
KIDNEY (Edwards).

In fig. 400, *A* is a vertical section of the kidney, *a* being its cortical substance, *b* the tubular, *c* the calyx and pelvis, and *d* the duct of the ureter. *B* shows the internal structure of the gland on a larger scale, where *a* is the terminal part of the tubes, *b* their medullary parts, and *c* their termination in the calyx.

766. **Peculiar Properties of Glands.**—Although the secreting organs may in a certain sense be compared to a filter, through which certain constituents of the blood alone permeate, there are nevertheless other effects, not merely mechanical, attending the process. Thus the secretions of different glands not only differ altogether one from another, but they differ from the constituents of the blood from which they are eliminated. Substances which enter into the composition of the blood in very small proportions, exist in the secretions in far more abundant quantity. Again, while the blood is alkaline the secretion proceeding from it is often acid; or, if alkaline, it is often much more intensely so than the blood.

Since different glands secrete different juices—those of the stomach, for example, the gastric juice, which is acid, and those of the small intestine, the intestinal juice, which is alkaline—it might be expected that some relation would be discoverable between their structure and the character of the secretion. No such relation, however, is observed. On the contrary, the same gland at different times, and under different conditions, secretes different juices without any simultaneous change in its structure.

767. **Influence of Nervous System.**—Whatever may be the nature of the function of secretion, it is certain that the nervous system exercises a powerful influence upon it. Although the experimental researches directed to this point have not been numerous, certain conclusions have been clearly enough established.

Thus, the division of the nerves which proceed to any particular gland has the effect of depriving the juices proper to that gland of their specific character, and of reducing them nearly to the condition of the serum of the blood. This result has been obtained in relation to the secretion of the kidneys in a course of experiments made by MM. Krimer, Brachet, Müller, and Peipers. Experiments attended with analogous results have been made on the liver by M. Bernard, and on the salivary and lachrymal glands by other physiologists.

The influence of the nervous system upon the salivary and gastric glands is familiar to everyone who has felt the "mouth water" at the sight, and their appetite stimulated by the odour, of agreeable aliments.

768. **Theory of Secretions Obscure.**—No part of the economy is involved in greater obscurity than the phenomena of the secretions, so far as relates to the specific character of the juices evolved by different organs. Some physiologists think that all the substances which enter into the composition of the products of secretion exist in the blood, and that the properties of the glands are limited to their power of allowing this or that constituent to transude through their tissues. But even admitting this, which, though true of some of the constituents of the blood, is far from being demonstrated of others, it remains still to explain the causes which determine the peculiar secreting power of the several glands. Why, for example, the liver secretes cholic and choleic acid? the kidneys urea, the stomach pepsine, and so on? It is true that the different permeability of the tissues may be supposed to explain the separation of some constituents of the blood rather than others by this or that particular gland; but even admitting

this somewhat vague hypothesis, a multitude of questions remain unexplained. Why, for example, when certain salts are injected into the blood, has their acid constituent a tendency to issue from the glands of the stomach, and their alkaline base from the kidneys ? Why do acid solutions in general issue on the stomach, and alkaline through other glands ? The specific poison secreted in the submaxillary glands of certain serpents (192) does not assuredly exist already formed in the blood of the reptile, since the introduction of its own poison into its circulation produces upon it the same effects as its bite produces on other animals.*

In a word, if it be true that the structure of the glands and the condition of the circulation influence the nature of the secretions, it is nevertheless evident that chemical reaction is produced in the glandular tissues upon the liquid which transudes from the vessels. It seems as though the tissues of the glands act upon the liquids which permeate them like so many different ferments, thus impressing various characters on the juices secreted.

769. **The Tegumentary Envelope.**—The body and its parts, internal as well as external, are coated with a membranous integument, which is everywhere continuous, so as to form a single organ. That part of this envelope which lines the internal cavities of the body and that which covers its external surface, have received different denominations ; the latter being called the *skin*, and the former the *mucous membrane*, from the circumstance of its surface being always lubricated with a specific liquid called *mucus*, secreted in its texture.

770. **The Skin** is at once a protective, sensitive, absorbent, and secretory organ.

As a protective envelope it is dense, strong, fibrous, subtle, and elastic. Its imperfect permeability prevents the too rapid dissipation of the internal fluids, and its imperfect thermal conductibility maintains the temperature of the organism. The external part of its thickness being divested of nerves and blood-vessels, it is insensible, and not susceptible of injury by external agents, thus protecting the internal nervous and vascular parts.

As a sensitive organ, its internal parts are provided with

* Béclard, Physiologie, p. 362.

nervous filaments of tactile sensibility, capable of excitation by external agents with more or less intensity, according as they are more or less numerous, and as the external insensible coating interposed between them and the exciting agent is more or less thin.

As a secretory, emunctory, and excretory organ, the skin is highly vascular and glandular, and perforated by innumerable minute ducts, which discharge from its surface specific fluids excreted within it, and pores through which it receives certain physical principles from fluids in contact with it.

Arteries in vast numbers terminate in the skin, which communicate by the intervention of capillaries with equally numerous and minute veins.

771. **The Magnitude of the Skin** is obviously subject to much variation, according to age, sex, stature, and bulk. M. Sappey measured that of a man of 45, above the middle height, and of full corporeal development, and found it to be about 2000 square inches.

The skin adheres to the general surface of the body, following all its inequalities, bending over its projections, and descending into its depressions. It is as though it were everywhere pasted to the surface.

772. **Effect of the Thickness of Skin.**—Its undulations and accidents correspond therefore nearly, though not exactly, with those of the parts which it covers. If it were an infinitely thin membrane, closely adherent to the parts, the correspondence would be rigorously exact. But, besides having a definite though small thickness, there is a layer of soft matter interposed between it and the surface of the parts which it covers, the effect of which is, like all coatings, to diminish the irregularities, rounding off in a greater or less degree the parts which project, and rendering the depressions less abrupt.

773. **Artifice of Sculptors.**—In the practice of their art, painters and sculptors have, with perhaps an excusable spirit of exaggeration, augmented or diminished, as best suited their purposes, this effect of the skin. When they have desired to represent youthful and effeminate beauty, as in the case of the Apollo, they have conferred upon the skin a more than natural power of equalising the surface; and when, on the contrary, their purpose has been to represent strongly developed muscu-

larity, as in the case of the Hercules, they have exhibited the body as though it were altogether divested of the integument.

774. **Structure of Skin.**—Taking the skin, in the ordinary popular acceptation of the term, as the tegumentary coating of the body extending from the exterior surface to the muscles and other organs, it may be considered as consisting of three distinct layers, the innermost of which is composed of cellular and adipose matter of soft texture. The middle, called the *true skin*, *derma* or *corium*, is a strong and tough web of interlaced fibres, pervaded by blood-vessels, lymphatics, and nerves ; and the external, called the *epidermis*, is a species of semi-transparent varnish, totally divested of all vascular or fibrous organs, and altogether insensible.

775. **The thickness** of this covering, including all its three layers, though varying much in different parts of the body, nowhere exceeds a small fraction of an inch ; and it will therefore be apparent that its structure can only be submitted to observation and analysis by means of the microscope.

776. **The Epidermis** is composed of a series of layers, superposed and cemented together. Each of these, when submitted to the microscope, is found to have a tesselated structure resembling a mosaic pavement, composed of irregular polygons, which are nevertheless so juxtaposed as to leave no vacant spaces between their edges. This appears to be formed gradually in proceeding from the innermost stratum outwards, by a liquid which exudes from the derma. Flowing over the surface of that membrane, it hardens and solidifies, and being then pushed outwards by a fresh portion of transuded liquid, it begins to assume the tesselated structure.

Colour.—Cutaneous Pigment.—In this state it is found that in each of its polygonal cells minute opaque-coloured corpuscles are included, which, being visible through the superposed layers, give the peculiar colour to the skin. In the negro race such corpuscles are black, in the Indian, red, in the Malay yellow or brown, and so on. In proportion as the race is more and more fair, the individual varieties of complexion due to this cause are more pronounced. Thus, we find a more striking difference of complexion between two individual Europeans than can be found between any two of the Negro or Malay races.

The layer of the epidermis which thus gives colour or complexion to the skin is called the *cutaneous pigment.*

In proceeding outwards from layer to layer of the epidermis the cuticle acquires greater and greater strength and consistency, so that while the deeper layers are soft, opaque, and granular, and soluble in acetic acid, the superficial ones are transparent, dry, and firm, and not at all affected by that acid.

777. **The Mucous Body.**—The deeper, softer, and recently formed part of the epidermis in immediate contact with the derma is called the *rete mucosum*, or *mucous body*. It must not be confounded with the mucous membrane, which covers the interior cavities of the bodies.

778. **Desquamation—Cutaneous Maladies—Corns.**—Since the exudation from the surface of the derma, which produces the inner layer of the epidermis, is incessant, the thickness of the epidermis would be indefinitely increased if a corresponding rejection of the matter composing the external layer did not take place. Such a rejection or *desquamation* of the superficial layer is accordingly as constant as is the reproduction which goes on in the innermost layer.

Indeed, it may be stated that in the healthy subject a perfect equilibrium is habitually maintained between these two processes of external desquamation and internal reproduction. Exceptional cases are nevertheless presented in certain maladies, such as the scarlatina and measles, in which the equilibrium is temporarily disturbed, the desquamation prevailing over the internal reproduction. On the contrary, the internal reproduction is sometimes so stimulated by the influence of pressure and friction, that it prevails over the external desquamation, and an undue thickness of the epidermis ensues, of which examples are presented in corns and callosities formed upon the feet by the unequal pressure and friction of ill-fitting shoes and boots, and on the hands of those who are habitually employed in certain kinds of labour.

779. **The Uses of the Epidermis** are obvious. That integument, inorganic and insensible itself, is placed between external objects and the sensitive structure of the derma, to intercept all injurious action upon the latter. It is mainly to the presence of this coating that the skin owes the important part which it plays in the economy as a protective agent. This inorganic varnish, thin as it is, opposes a generally impassable barrier to the most active toxic substances, provided they are not of such a nature as to effect its chemical decomposition. Were it not for this, many of the substances which we now handle with impunity would be absorbed by the capillaries of the derma, and being carried into the organism by the circulation, would immediately produce effects more or less injurious or destructive. When the epidermis has been removed by a blister, substances applied to the denuded derma are readily absorbed, and produce their characteristic effects.

780. **Papillæ.**—The external surface of the derma, upon which the epidermis rests, is thickly covered with projections, called *papillæ*, the form of which is generally conical, with somewhat rounded points, the bases of the cones being implanted in the derma. The minuteness and closeness of these projections may be conceived when it is stated that they have been

variously estimated by microscopic physiologists at from five thousand to a million per square inch.

A view of a part of the external surface of the derma of the foot, showing the arrangement and form of these papillæ, is shown in fig. 401, magnified about 100 times.

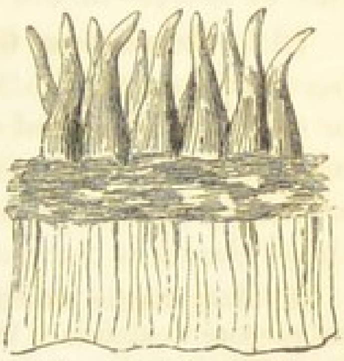


Fig. 401 (Breschet).

The surface of the derma thus bristling with those minute projections may not inaptly be compared to the pile of velvet.

Though they are everywhere thus minute in magnitude, and closely juxtaposed, they vary in number, magnitude, and arrangement, in different parts of the body. In the palmar surfaces of the hands and the plantar surfaces of the feet, they are more numerous and more closely crowded together than elsewhere.

Their direction is generally, but not always, at right angles to the derma. In some parts they are inclined to it. Their form is mostly conical, but in certain parts they take the form of slender cylindrical rods, and in some places are shaped like little mushrooms, connected by a short pedicle with the derma; a form which is supposed to have some relation with the special sensibility of the part where it prevails.

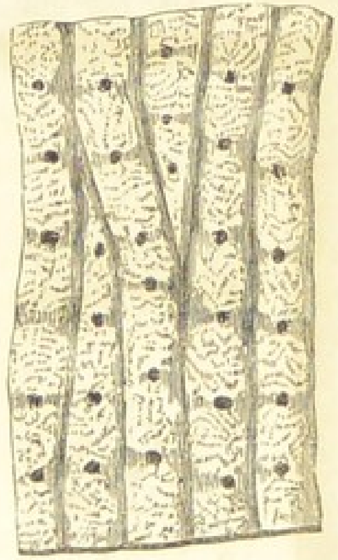


Fig. 402 (Breschet).

In the palms of the hands and the soles of the feet, the papillæ are arranged in parallel rows, generally following the direction of the wrinkles of the skin. In the balls of the fingers and toes they are arranged in parallel curves of a parabolical or elliptical form. Their course under the epidermis is in these cases indicated by corresponding lines on the external surface of the skin, which are visible to the naked eye upon the palm of the hand and the balls of the fingers.

A magnified view of these superficial lines formed upon the skin is shown in fig. 402, the dark spots being the embouchures of excretory ducts, which will be presently described.

A small artery enters each papilla, which at its summit becomes a capillary, which carries back the blood to the venous vessels of the derma. According to M. Sappey, each papilla also contains a small lymphatic branch, which subdivides within it into still more minute ramifications.

781. **Papillary Nerves.**—The opinions of physiologists are much divided as to the course of the nervous filaments in them. According to Pappenheim, the nervous filaments form sometimes a loop, and sometimes a plexus, at the base of each papilla, without penetrating it. Todd and Bowman have, however, traced the nerves half-way up the papilla; and although they have lost sight of them there, analogy justifies the conclusion that they go further. According to Gerber, the nerves

terminate in a loop at the apex of the papilla, a single loop being formed in the small papillæ, and six or eight producing a tuft or rosette in the larger ones.

782. **Sebaceous Glands.**—Minute glands which secrete a peculiar humour, called *sebum*, a Latin word, signifying tallow or suet, are deposited in the derma. These discharge the matter which they secrete into the follicles of the hair, each having a small duct which opens into the follicle. The magnitude of these glands is compared to that of a grain of millet.

The fatty matter which they secrete is generally considered as having for its purpose to maintain the suppleness of the skin and to oil the hairs. Its composition is not the same in different parts of the body.

783. **Sudorific Glands.**—Other glands, appropriated to the excretion of sweat, are deposited in the subjacent stratum of adipose cellular matter. From each of these a duct proceeds which passes in a spiral course outwards through the derma, and in passing through the epidermis takes the form of a cork-screw. In issuing through the surface of the derma these sudoriferous ducts pass in the spaces which intervene between the papillæ. In the palms of the hands, the soles of the feet, and other places where the papillæ are ranged in parallel rows, they are generally disposed in pairs, one at each side of each sudorific duct.

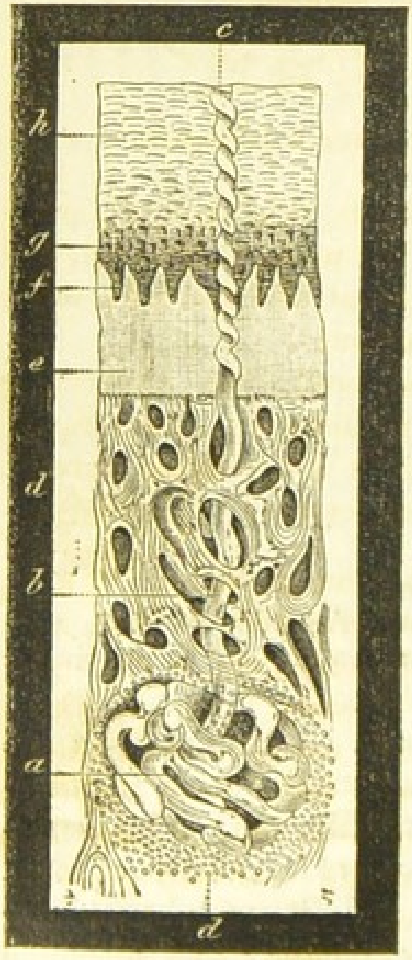


Fig. 403 (Mandl).

The general structure of the skin, as here described, will be more clearly understood by reference to fig. 403.

In this figure the skin is represented as magnified forty times in its linear dimensions. *a* is a sudoriferous gland; *b c* the duct; *d* the subcutaneous, cellular, and adipose tissue; *e* the derma; *f* the papillæ; *g* the rete mucosum; *h* the epidermis.

In figure 404 is presented the view of the root of a hair and its follicle, magnified 200 times in its linear dimensions. *a* is the stem or shaft of the hair, cut transversely; *b* the inner and *c* the outer layer of the epidermic lining of the follicle; *d*, the dermic or external coat of the follicle; *e*, imbricated scales about to form a cortical layer on the surface of the hair.

784. **Skin Contractile—Effect of Cold.**—When the skin

being previously warm, is suddenly exposed to cold, it contracts and shrinks. All the sudoriferous ducts suddenly suffer a great diminution in their calibre, and may even be altogether closed. The excreted liquid with which they had been filled is thus driven back to the sudoriferous glands, and as this, like all liquids, is incompressible, a corresponding quantity is driven from the glands into the circulating apparatus, by which it is transported to various parts of the body, of which it deranges the functions and produces corresponding maladies.

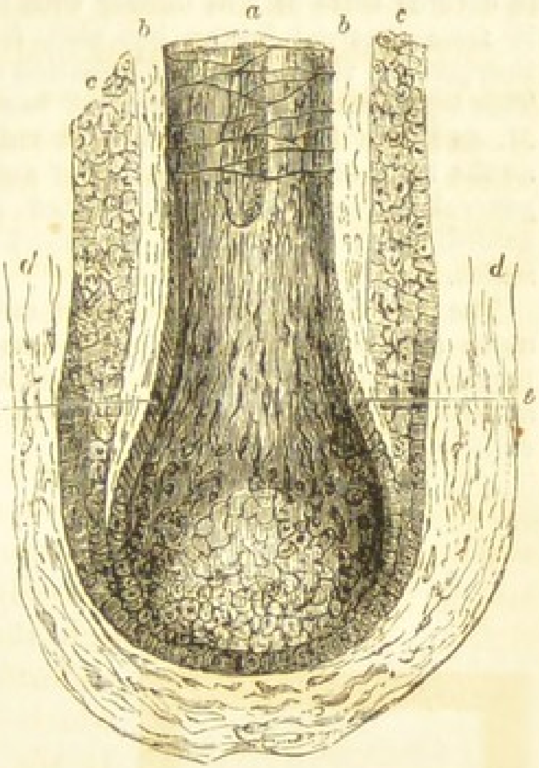


Fig. 404 (Kohlrausch).

That transpiration is one of the expedients by which the organism expels deleterious principles is proved by the yellow sweat of jaundiced patients, the urinous sweat of those who suffer from a retention of the urinary exertion, and the fœtid odour proceeding from the sweat of those who suffer under certain maladies, such as rheumatism.

When these phenomena are considered, the importance attached by physicians, ancient and modern, to transpiration and to the production of profuse sweat as a means of cure in certain acute maladies, will be easily understood.

Casting the Skin.—In other mammifers, as well as in man, the epidermis is gradually rejected and renewed, so that, after a certain interval, like other parts of the organism, it undergoes a complete change. There are other species, however, which, instead of changing thus gradually their external skin, change it suddenly at certain epochs. At such times they acquire a completely new epidermis, and, issuing from the old one, leave it unbroken and without change of form, like a sheath or mould, from which their bodies are withdrawn. Serpents and some other animals present examples of this remarkable phenomenon, which is called *casting the skin.*

785. **Epidermic Appendages.**—In the inferior species of mammifers the skin presents several remarkable peculiarities. With a very few it is completely divested of all external covering, but in most cases it is covered more or less thickly with hairs, which not only serve to protect it from external injury, but also, from being non-conductors of caloric, theyprevent the too rapid dissipation of the heat developed in the organism. This tegumentary appendage has been regarded of such importance that M. de Blainville, one of the most eminent zoologists, proposed to adopt it as the basis of the classification of animals, which he divided into three general classes, to be denominated pilifers, pennifers, and squamifers, according as the external tegument is covered by hairs, feathers, or scales.

The hair developed on different animals, and on different parts of the same animal, receives different names according to its different properties, mechanical and physical. Thus, the stiff, strong, and pointed appendages produced upon the skin of the porcupine and hedgehog are called *quills*.

Fig. 405.
THE PORCUPINE.

Those which are less rigid—such, for example, as are found on the boar—are called *bristles*. The more flexible, fine, and soft hairs which so thickly cover the skin of some animals, and which are generally straight, lying parallel to each other, are called *fur*. When they are finer and twisted more or less together, as in the coating of goats, they are called *hair*; and when finer still, and more curled and twisted, as in the coating of sheep, they are called *wool*. The finest filaments, which are usually collected next the skin and covered by the coarser, are called *down*.

786. **Fur and Wool.**—The colour of fur or wool is subject to great variety, but may be classed generally under one or other of the five tints, white, black, brown, reddish, or yellowish. The peculiar colour is supposed to depend upon a fatty substance, which is soluble in alcohol at the boiling temperature. When this oil is eliminated, the fur, whatever be its colour, is reduced to a yellowish-grey tint.

The presence of sulphur in hair of different kinds has been ascertained; and it is to the combination of this with iron that black hair owes its colour. Factitious dyes for hair have been contrived upon this principle; the sulphur which is generally found in them, entering into combination with the salts of lead, mercury, and other metals, produces sulphurets, which give the hair a dark tint.

The hairs constituting the fur of animals sometimes have an uniform colour throughout their entire length, but are generally darker towards their extremities than towards their roots; sometimes they present alternations of white and coloured parts. They generally differ in colour on different parts of the body, the tint being for the most part darker upon the back than upon the belly. When they vary in colour so as to form spots or streaks, these with animals in the natural or wild state are almost always disposed symmetrically on each side of the spine. It is remarkable, however, that this regularity is not found to prevail in the case of animals reduced to a state of domesticity.

In general, the hairs fall and are reproduced at certain seasons of the year—most frequently in spring and autumn, when the animals are said to change their coats. This phenomenon is often attended, not with a change of colour only, but with very considerable modifications in the rich-

Fig. 406.
THE SQUIRREL.

ness, fineness, and abundance of the fur. Thus, in the case of the common squirrel, the fur, which in summer has a dark red tint, acquires a bluish-grey colour in winter.

In this season the fur is generally much thicker and finer than in summer, and supplied with a considerable quantity of fine down next the skin, a provision of nature obviously made for the preservation of the temperature at a season when it might be injuriously lowered by external cold. The same beneficent provision is observable in comparing the fur of tropical with that of polar animals. In cold climates the fur is rich, thick, and abundantly furnished with down; while in warm countries it is short, stiff, and sparse.

In furs used for clothing and ornament, the qualities desired are richness, fineness, softness, and brilliancy. From what has been just observed, it will be apparent that such qualities can only be found in the coldest climates, and especially during the season of winter. We find, accordingly, that the principal localities from which the commerce in furs is derived are the extreme northern parts of the old and new continents.

When the roots from which the hairs are developed are in extremely close contiguity, these epidermic productions, instead of issuing separately from the skin, come to be cemented together, so as to form solid scales, which are seen upon the bodies of certain species of mammifers, such as the pangolin, or scaly ant-eater, of Bengal and Central Africa, and the common armadillo.

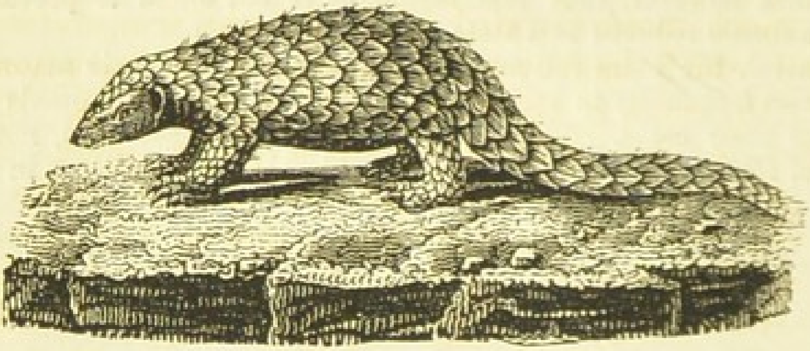


Fig. 407.

THE PANGOLIN, OR SCALY ANT-EATER.

787. **The Plumage of Birds** is an epidermic production altogether analogous to the hair of mammifers. Its mode of production is also similar, and it is subject to a like growth and change. The moulting of birds at certain seasons obviously corresponds to the changing of the coats of mammifers.

The form and mechanical and physical properties of plumage is subject to extreme variation. There are some birds whose feathers are entirely divested of barbs, and resemble the quills of a porcupine. The cassowary presents an example of this (fig. 108). The feathers of other species are furnished with barbs and barbules, which are stiff and are hooked one in another, so as to form a surface which the air cannot easily penetrate. The feathers of the wings of the eagle and the crow offer examples of this. There are other species, on the contrary, whose feathers are furnished with barbs and barbules which are long, light, and pliable, and which are characterised by extreme delicacy and softness. The feathers composing the tail and wings of the ostrich present examples of this. In fine, there are other species, certain parts of whose plumage assume the form of down. Storks and swans are examples of this class.

For brilliancy and beauty of colour, the plumage of birds far exceeds the hair of mammifers, and equals in splendour the hues of the finest flowers and the most dazzling jewels. In general, the plumage of the male in this respect surpasses that of the female. The hues of the plumage are also subject to remarkable changes, as well with the growth as with the seasons. The young bird is seldom adorned with colours with which it will be decorated when full-grown, and the plumage of winter is often altogether different to that of summer.

Like the hair of animals, the plumage of birds is adapted, by its physical qualities, to their habits and mode of life. Thus, the feathers of aquatic birds are coated with an unctuous matter, which renders them not only impermeable to water, but repulsive to it; so that the animal after plunging into that liquid emerges from it perfectly dry.

788. **Animal Heat.**—While all inorganic bodies have a tendency to a thermal equilibrium with the medium which surrounds them, animals, on the contrary, have a thermal condition different from and independent of the mediums in which they live. The human body, as is well known, has a temperature much more elevated than the mean temperature of the air, and which moreover is subject to no variation, being sensibly the same at the tropics and at the poles. There is, therefore, in the animal organism a proper source of heat; since, to sustain this constant temperature, the losses of heat constantly produced by superficial radiation and other causes must be repaired.

It is demonstrated in physics that a certain evolution of heat always attends the combination of oxygen gas with the various bodies for which it has an affinity, but more especially with carbon and hydrogen, its union with the one producing carbonic acid, and with the other water. Now, it has already been shown that in respiration a certain quantity of free oxygen enters the organism, and that certain quantities of carbonic acid and the vapour of water are expelled from it. It follows, therefore, that a combination of oxygen with carbon and hydrogen takes place in the system, and that a corresponding evolution of heat in the economy must be produced. It remains to ascertain whether the actual quantity of heat which would be evolved in such combinations be equal to that which the animal loses by radiation, evaporation, and other causes.

789. **Quantity of Heat Developed.**—Taking the average volume of air respired in a day as 450 cubic feet, the chemical and thermal phenomena developed in respiration are stated as follows:

ANALYSIS OF THE MEAN DAILY RESPIRATION OF AN ADULT MAN, AND OF THE MEAN QUANTITY OF HEAT DEVELOPED DAILY IN HIS ORGANISM.

	grs.
Total quantity of air respired in 24 hours (450 cubic feet) . .	241150
Oxygen contained in this	55700
Free oxygen expired	42617
Oxygen absorbed	13083
Carbonic acid expired	15655
Oxygen contained in it	11323
Carbon contained in it	4332
Aqueous vapour expired	1980
Oxygen contained in it	1760
Hydrogen contained in it	220
Heat developed in the internal combustion of carbon, expressed	lbs.
by the weight of water it would raise from 32° to 212° . .	50
Heat similarly developed by hydrogen, similarly expressed . .	10·8
Total heat developed in the organism, similarly expressed . .	60·8

It appears, therefore, that the total quantity of heat developed in twenty-four hours by a full-grown man in health, is such as would raise sixty pounds weight, or six gallons, of water from the temperature of melting ice to that of boiling water.

Since the temperature of the blood remains invariable, it follows that the quantity of heat dissipated by the body in various ways in a given time must be equal to the quantity produced in the same time. The manner in which this loss of heat takes place is ; first, by radiation from the surface of the body ; secondly, by the contact of air and other external bodies whose temperature is lower than that of the organism ; thirdly, by cutaneous and pulmonary evaporation ; and fourthly, by the heat imparted to the food and drink, and to the air taken into the lungs, all of which have generally a temperature lower than that of the blood.

It is calculated that about three-tenths of this loss of heat is produced by evaporation as well as by the heat absorbed by food and drink, and that the remaining seven-tenths escapes by radiation and by the contact of external objects.*

* Further particulars respecting animal heat will be found in the Handbook of Nat. Phil., Heat, Chap. X.

CHAPTER XI.

THE SENSES.

790. Those faculties, by means of which we are put in communication with the external world, and enabled to perceive the objects and phenomena around us are called the *senses*. It has been already explained that the sensitive nerves are the conductors by which the impressions received from external objects, are transmitted to the brain which is the seat of perception and thought. The parts of the body on which external objects thus act, are called the *organs of sense*. Each of these is so constructed as to be susceptible of being impressed in a peculiar manner by such objects, and of conveying such impressions to the terminal filaments of the sensitive nerves which overspread its structure. Such impressions are propagated by the nerves from the organ to the brain, as an electric current in the telegraph is propagated along the conducting wire from the station giving to the station receiving the signal.

791. **Number of Senses.**—Among the parts of the body which are susceptible of such excitement, there are some which are sensible to particular agencies only, and totally insensible to others. Some physiologists have, therefore, maintained that the number of senses should be made to correspond with the number of distinct sources of external excitement, and instead of five, as commonly enumerated, have contended for ten. Although questions of this order are not without importance, the objects of the present volume will be better served by adhering to the generally received classification of five senses :— the touch, or tactile sense, the taste, the smell, and the senses of hearing and seeing.

792. **Position of Organs.**—Like all the organs which are subordinated to the will, those of sense are placed symmetrically with relation to the median plane. Two only, those of seeing and hearing, are double, consisting of similar structures, similarly placed on each side of that plane. The nerves which proceed from the organs of each pair, converge towards the

median plane, and unite at a certain point in that plane before arriving at the brain. The single organs endowed with the functions of each of the other senses, are so placed, that they are divided symmetrically by the same plane, each half being absolutely similar to the other, and every point on the one side having a corresponding point at the other.

793. **Their Structure.**—Each organ of sense may be considered as consisting of two parts, one in which the nervous filaments receive the excitement of the external object, and the other, whose function is to modify such excitement, so that it may be sufficient to produce perception, but not such as to injure the structure of the organ.

794. **Protective Accessories.**—This latter class of accessories of the organs of sense consists sometimes of bony, sometimes of cartilaginous, sometimes of membranous parts, and sometimes of all these three combined. They consist also of voluntary muscles, by which the organ is moved and directed ; of glandular parts, by which lubricating fluids are secreted ; of vascular apparatus, to maintain the local circulation ; and, in fine, of a system of nerves of motion, by which the parts just mentioned are brought into action.

795. **Local Arrangement.**—Of the five organs of sense four are established in the head, and consequently in close contiguity with the brain, with which they are immediately connected by special nerves. The fifth, which is the skin, covers the whole surface of the body, every part of which is by it rendered sensible to the contact of external agents, the impressions of which are propagated to the brain by an infinite number of nervous filaments which ramify through the skin, and, proceeding from thence, converge into trunks and into bundles called plexuses, and finally enter either the spinal cord by the lateral foramina already described, or penetrate directly into the brain itself.

796. **The Touch.**—The tactile organ constituting the entire tegumentary covering of the body is at once the most general in its susceptibilities, and the most precise and certain in its results. It is accordingly that to which we almost instinctively appeal when we desire to escape from the illusions to which the other senses are obnoxious. The Apostle who incurred the

reproach of being wanting in faith because he doubted the evidence of his eyes, was convinced by the result of his touch. While the other organs are thus occasionally the source of hallucinations, the sense of touch, although it may be rendered more or less exalted or even entirely annihilated, is never perverted ; so far as it affords indications at all, they are never deceptive.

797. **The Special Senses.**—The other organs of sense, as well as that of touch, are called into action by the impressions they receive from external agents ; but they differ from the tactile sense, inasmuch as each of them is only susceptible of impressions produced by certain special agencies, and hence they have been distinguished by physiologists as *special senses*, while the tactile has been denominated the *general sense*. While the tactile organ overspreads the entire body, the special organs are all seated in the anterior part of the head, and therefore in the immediate neighbourhood of the brain. The organ of taste is established at the very entrance of the alimentary canal, there to stand sentinel, challenging as it were all that ask for admission, and refusing such as it deems unsuitable. The organ of smelling is in like manner established at the entrance of the respiratory apparatus, to give notice as it were of the presence of obnoxious principles in the air inspired. The organs of sight are established in the front of the head, with their axes always directed forward, so as to present without any fatiguing effort a perception of all objects placed before us. The organs of hearing are not presented forwards, but are implanted at each side of the skull, the one commanding the range of the hemisphere to the right, and the other of that to the left.

798. **Manifestation of Design.**—Without mentioning the innumerable circumstances in the details of these several organs, which will be presently developed, it is impossible to contemplate even for a moment the mere positions assigned to them in the economy, without being struck with the manifestation of design and contrivance which they present.

799. **Organs of Taste and Smell.**—The organs of taste and smelling may be regarded as necessary accessories and appendages of the general apparatus of nutrition, and therefore more or less essential to the maintenance of animal life ; but the

organs of seeing and hearing are obviously limited in their purpose to the relations of the animal with the external world, and consequently less indispensable to the mere maintenance of life. It is found accordingly that while the senses of tasting and smelling are generally maintained until the close of life, those of seeing and hearing are often impaired by time, and sometimes altogether destroyed, while the other vital functions remain unimpaired.

800. **The Common Principle.**—The organs of sense compared one with another vary like the external agents by which they are excited. Nevertheless, a close examination of the structure and functions will show that they have been designed and constructed upon a common principle, and that the points on which they differ are those accessories by which that common principle is so modified as to be rendered conformable to the special agency by which each is excited.

The common principle in all the organs is a membrane which is excited by some external physical agent. In the case of the general tactile sense this membrane is the *derma*, or inner skin, which bristles with minute eminences called *papillæ*, in which the nerves of the tactile sense terminate. The membrane which connects these papillæ is spread over the whole body, but is not everywhere equally sensitive, the papillæ being more numerous in certain places than in others.

The membrane of the sense of taste is the mucous membrane of the tongue and some other parts of the mouth, which, like that of the skin, also bristles with papillæ. In both cases the impression is made by the direct contact of bodies capable of affecting the organs. In the case of the organ of smelling the sensitive part is the *pituitary membrane*, in that of hearing, the membranes of the *tympanum*, and in that of seeing, the *retina*. These membranes, which are severally susceptible of receiving impressions of the peculiar physical agencies to which each organ is adapted, will be described more fully hereafter ; meanwhile it may be stated that in all cases the impression is produced by the direct contact of the physical agent with the susceptible membrane. In the case of the sense of touch the object felt is brought into contact with the skin ; in the case of that of taste it is brought into contact with the tongue ; in the case of smelling, the odoriferous effluvia come into contact with the pituitary membrane ; in the case of hearing, the air in a state of pulsation strikes upon the membrane of the tympa-

num ; and, in fine, in the case of seeing, the pulsations of the luminiferous ether impinge directly upon the retina.

801. **The Special Accessories.**—The accessories of the organs, in which necessarily one differs more or less from another, are provisions by which the action produced upon the several membranes is regulated, and by which the organ is protected.

The protecting arrangements moderate the intensity of the exciting agent so as to preserve the efficiency of the organ, which would otherwise be impaired by undue intensity of excitement. Without going much into the details of the construction of the organs of sense, such provisions will be obvious. Thus the epidermis which, as has been already described, everywhere covers the derma, is interposed between the object which is touched and the sensitive papillæ. This protecting influence is accordingly varied in different parts of the body, being thinner where the tactile sensibility needs to be greatest.

In like manner the epithelium is interposed for the protection of the mucous membrane of the tongue ; and, since greater sensibility is there required, it is proportionally thinner, giving more effect to the agency by which the sense is excited. A similar epithelium protects the pituitary membrane ; but it is in the cases of the ear and the eye that such protective arrangements are most striking. The force of the aërial pulsations which act upon the tympanum are moderated by a multitude of obstructive provisions, which may not inaptly be called dampers, placed between the auditory nerves and the external opening of the ear. In the case of the eye the protective provisions are still more numerous and admirable : the eyebrows form a shade to give partial relief from the intensity of the light ; the eyelids are movable screens by which the action of the light can be interrupted at will ; the iris which surrounds the circular hole called the *pupil*, by which light is admitted to the retina, is a contractile ring which admits of being expanded and contracted so as to admit a greater or less quantity of light. When the light becomes too intense, this iris is acted upon by muscles suitably placed so as to diminish the diameter of the pupil, and consequently to diminish in the proportion of the square of that diameter the quantity of light admitted to the retina ; and when the light is too feeble to produce a sensible impression on the retina, unless its quantity is increased, a contrary action takes place upon the iris, by which the pupil is enlarged.

802. **Provisions for Efficacy.**—On the other hand, a series of provisions are not less admirably adapted so to augment the intensity of the impressions produced upon the organs as to insure their efficiency, and there is probably nothing among all the beautiful arrangements observable in the organised world in which means are so admirably adapted to their ends as in these provisions, which nature seems to have made to surround man with all the instruments necessary to enlarge the domain of his intelligence, and to extend, without any assignable limit, the sphere of his observation.

Thus, in the mechanism provided for the sense of touch, not only is there a greater multiplication of the sensitive papillæ under a more delicate epidermis there where the touch requires greatest susceptibility, but a mechanical instrument has been provided of exquisitely perfect structure by which the sensitive surface can be applied in the most efficient manner to the objects under observation, so that the texture of their surfaces, their forms, magnitudes, and various other physical qualities, can be perfectly determined.

In immediate juxtaposition with the organ of taste, the salivary glands, as already described, have been provided, by which a liquid is secreted, in which is dissolved the particles to be tasted; so that their solution acts upon the epithelium of the tongue, and, through it, upon the sensitive papillæ of the mucous membrane within it, with infinitely greater effect than could be produced by the action of any solid particles, even in the most minute state of pulverisation.

In the case of the olfactory organ, the sensibility is exalted by augmenting the extent of surface of the pituitary membrane which is brought into contact with the air, by spreading out that membrane over the convolutions of the bony structure of the nose.

In the case of the ear, the intensity of the pulsations of the air is augmented by the concave form, given to the external ear, and the gradual contraction of the auditory passage leading from the external aperture of the ear to the tympanum, the form of which has an obvious analogy to that of an ear-trumpet.

CHAPTER XII.

THE TOUCH.

803. **Tactile Sensibility** is a property common to the entire integument of the body, but the sense of touch in its common acceptation is applied exclusively to the palmar surface of the hand. It is not, however, altogether on account of the high degree in which that part of the skin possesses this sensibility, that the hand has been considered as the peculiar organ of touch. The mechanism by which it can be applied with such admirable facility and promptness to all objects within reach, so as to feel their form, magnitude, texture, and certain other qualities (99, 131, 132, &c.), has a large share in conferring upon it these tactile functions.

804. **Its Utility.**—The sense of touch is so perfect that it has been regarded by many as the most useful of the senses, and as being the chief source of intelligence. It is certain that the impressions produced by the other senses, and more especially by sight, would be illusory and deceptive if they were not, as they are, instinctively corrected by those of touch. It is difficult, however, to institute a comparison between the value of other senses, and that of touch, because, though sight or hearing may be absolutely lost, the sense of touch can never become altogether extinct so long as life continues.

805. **Its Variation.**—Tactile sensibility, as already stated, exists in very different degrees in different parts of the body. Of the internal membranes the extremity of the tongue is the most sensitive. The lining of the eyelids and the membranes of the nasal passages, the mouth, the upper part of the œsophagus, and some other internal parts, have also the tactile sensibility, though in a much less degree.

806. **Tactile Nerves.**— All parts which possess the tactile sensibility derive their nerves from the cerebro-spinal axis. The mucous membrane which lines the digestive canal, the bladder, and the excretory ducts, possesses no tactile

sensibility, neither does the internal membrane of the vascular apparatus. We neither feel the passage of the products of digestion through the intestine, nor of the blood through the veins and arteries, nor of the lymph and chyle through the lymphatics. The membranes which line these vessels and ducts, however, though not properly endowed with the tactile sense, have a certain sensibility which is manifested by the pain which follows any derangement.

807. **Muscular Sense.**—Certain impressions commonly ascribed to the tactile sense are, in fact, the combined result of that sense and of the consciousness of muscular action. Thus, when by the application of the hand, we ascertain that a body is soft or hard, we arrive at the perception by the consciousness of the muscular power necessary to change the form of its surface by the pressure of the fingers or of the hand. If that force be small, the body is said to be soft; if it yield only to a more intense muscular action, it is considered hard; if its parts resist separation by the force of the hands, it is said to be tough. In like manner, when a body sustained in the hand is perceived to be heavy or light, it is not properly or, at least, not exclusively, the sense of touch which produces this perception, but chiefly the consciousness of the muscular force necessary to be exercised to support it. Such impressions therefore may be regarded as the mixed results of the tactile and the muscular sense.

808. **Conditions of Tactile Sensibility.**—Like all the other organs of sense, the tactile organ is only efficacious in so far as it is supplied with nerves, and as these nerves have uninterrupted communication with the brain or seat of perception. The more abundantly therefore any part of the integument is supplied with such nerves, the greater will be its sensibility; but whatever be its richness in nerves, if their communication with the cerebro-spinal axis be interrupted, either by section or by paralysis, the tactile sensibility will be entirely destroyed.

Thus, if the sensitive nerves of the hand be paralysed or divided, that member will be rendered altogether insensible. The individual thus affected will be no longer capable of perceiving by his touch the form, magnitude, temperature, or even the presence of external objects. If a body be placed in his hands, he will unconsciously let it fall; for although—the motor nerves of the hand and arm being still perfect—he is capable of grasping and supporting the object, his touch fails to give him notice when and how to produce the necessary muscular action. In such cases the sight

may supply, to a certain extent, the absence of the touch. If he see the object placed in his hand he will know when and how to grasp it, and may hold it so long as his eye is directed to his hand, but the moment he looks elsewhere he will let it fall.

In like manner, if the nerves of sensation of the leg be divided or paralysed, the motor nerves being preserved, the powers of sustentation and locomotion are materially deranged. The sense of touch directs, in a great degree, the action of the motor nerves, and altogether so in the case of blind persons. In the case here supposed, the individual no longer feels the ground on which he stands or walks, and, except so far as he is aided by his sight, he will find it difficult or impossible to maintain his equilibrium.

809. **Papillæ not all supplied with Nerves.**—From what has been already explained of the structure of the skin, it will be understood that the seat of the tactile sense is in the papillæ of the derma, at least so far as these papillæ are pervaded by nerves. It appears, however, from the researches of Messrs. Wagner and Kölliker,* that all the papillæ of the derma are not supplied with nerves. The sensibility, therefore, of any part of the skin, other things being the same, will be proportional, not to the total number of papillæ, but to the total number of *nervous papillæ* included within a given space.

It appears also, from the same researches, that within the nervous papillæ there is included a pear, or rather pine-apple-shaped mass, composed of fibrous tissue of a harder and tougher texture than the other parts of the papilla, upon which the nerves are spread, and which serves as a support or surface of reaction for them, in the same manner as the nails supply points of reaction for the flesh of the last phalanges of the fingers in the act of touch. Kölliker assigns to this hard pear-shaped mass which lies under the nerves an analogous function, the nerves being pressed against it in the act of touch.

810. **Use of Epidermis.**—The epidermis, which everywhere covers the derma, serves not only to protect the highly sensitive papillæ, but is a sort of damper or regulator to the sense of touch. Divested of the epidermis, the contact of the papillæ, instead of producing the proper sense of touch, would produce pain, as is rendered manifest when the epidermis has been separated from the derma, where a blister has been produced. In fact, the sensibility of naked papillæ is too exaggerated for use.

* A. Kölliker. Ueber den Bau der Cutispapillen und die sogenannten Tastkörperchen in R. Wagner's Zeitschrift für wissenschaftliche Zoologie, von Siebold und Kölliker, 1st vol. 1 ed. 1852.

Other things being the same, it will be evident, therefore, that the tactile sensibility of the different parts of the body varies with the thickness of the epidermis.

811. **Its Thickness increased by Pressure and Friction.**—By a beneficent provision of nature, the frequent exposure of any part of the integument to external pressure, friction, or other force, the continuance and repetition of which might injure the delicate structure of the papillæ, is attended with a gradual thickening of the epidermis. Thus, those who labour with the hands soon find the palmar epidermis to become thick and hard; and while the organ is better suited to the purpose to which they are compelled to apply it, it loses in a proportionate degree its delicate sensibility.

In like manner, those who walk with bare feet soon find the plantar epidermis thicken in the same manner.

A tight shoe, instead of destroying the epidermis and wounding the derma, thickens the former, and sometimes produces corns and other like excrescences.

812. **The Relative Tactile Sensibility** of different parts of the body was experimentally determined by M. Weber,* by the following ingenious expedient :—

The points of a pair of compasses being rendered sufficiently blunt and round to prevent their puncturing the skin, are adjusted at a certain distance asunder, and then gently pressed upon the skin, at the part where its tactile sensibility is desired to be ascertained. If the distance between them be not less than a certain limit, the pressure will produce a perception of the two distinct points. But if the distance between them be gradually diminished, and the experiment be repeated, it will be found that when the distance separating them is reduced to a certain minor limit, the perception produced will be that of the pressure of *a single point*, and the same will of course be true for all less distances. Now, this minor limit of distance which produces the perception of a single point, although the pressure of two separate points be made, varies in different parts of the body; those which have least sensibility having a greater, and those which have most sensibility a less minor limit of distance.

If, for example, the points of the compass being set at three inches asunder, are pressed against the skin of the back, the perception produced will be that of two separate pressures; but if the distance between the points be two inches or less, then the pressure on the back will produce the impression of only a single point. If the compass, instead of being pressed upon the back, the points being separated by the distance of two inches, be pressed upon the skin of the cheek, the eyes being blindfolded, a distinct

* De subtilitate tactûs diversâ in diversis partibus sensui dicatis, in the work entitled: De pulsu, resorptione, auditu, et tactu. Annot. Anatom. et Physiolog.; in 8vo. Leipsig, 1834.

perception of the two points will be produced. But if the points be then gradually brought closer together till the distance between them is reduced to $\frac{1}{10}$ of an inch, the perception will be only that of a single point; and the same effect will be produced for all less distances.

By repeating these experiments upon various parts of the body, Weber determined the mean minor limits of the distance between the points at which the perception would become single at various parts of the body; and, assuming that the tactile sensibility is inversely proportional to this minor limit of distance, he thus obtained a numerical measure of it. The following are among the results which were obtained, the distance between the points being expressed in hundredths of an inch :—

	Distance between points, hundredths of an inch.
End of tongue	4
Palmar surface of first finger-joint	6
Palmar surface of the other finger-joints	12
Lips	16
Cheeks and eyelids	40
Back	200

The following curious experiment may be explained by the principle thus established :—

Let the legs of the compass be so adjusted that the distance between the points shall be reduced to sixteen hundredths of an inch, and let the instrument be then applied to the cheek, the impression will be that of a single point. Let the points be now moved along the cheek but still pressed upon it, towards the lips. As they approach the lips, the impression which was previously single will become gradually double, and decidedly so when the points arrive at the lips. The effect produced is as though the legs of the compass were gradually opened to a greater and greater distance as they are brought nearer to the more sensitive parts of the integument.

The result of experiments made in this way shows that the tactile sensibility generally decreases, proceeding from the extremities of the members towards the trunk. Thus, for example, the delicacy of touch is less in the fore-arm than in the hand, and less in the arm than in the fore-arm. It is less in the leg than in the foot, and less in the thigh than in the leg. On comparing the members one with another, it appears that it is less in the legs and feet than in the arms and hands. It is less also in the dorsal than in the palmar surface of the hand, and less, in like manner, in the superior than in the plantar surface of the foot. It is less in the elbow than in the bend of the arm; less in the knee than in the bend of the leg; less in the shoulder than in the armpit, and so on.

813. **The Local Variation of the Tactile Sensibility** produces singular differences in the judgment we form of the shape and volume of the bodies we touch

If the point of a pencil, cut in a triangular form, be pressed upon the tongue, a distinct impression of its triangular shape will be produced; but if the same point be similarly applied to the skin of the cheek, no other impression will be produced, than that of the contact of a point. If a lock of hair be pressed tightly on the cheek no other impression will be produced except that which a ribbon or any other web of the same breadth would produce; but if the same lock be similarly applied upon the palmar surface of the first joint of the finger, or still more upon the tongue, the separate hairs composing it will be felt.

At the parts of the skin where the tactile sensibility is least developed, we are deceived with regard to the volume of the body we touch, inasmuch as our only estimate of magnitude has for its unit the least distance at which we are sensible of the pressure of two separate points. Thus, for example, when we feel distinctly the two points of a compass pressed upon the cheek at half an inch asunder, it is impossible to form an exact appreciation of this space. If we compare it with the impression habitually produced by the fingers, we would necessarily judge it to be much smaller than it is. For the same reason, if instead of the two points of a compass, any body, the diameter of whose surface does not exceed the distance between these points, would produce the same deceptive impression. If such a body be pressed upon the back, or any other part of the body having a low degree of tactile sensibility, it would be impossible either to obtain any perception of its form or its volume.

814. **The Appreciation of Heat by the Touch** is most fallacious. If two bodies be very different in temperature, the touch will sometimes inform us which is the hotter; but, if they be nearly equal, we shall be unable to decide which has the greater or which the less temperature.

The sense of touch, however, totally fails in informing us of the comparative quantities of heat in bodies. It cannot be at all affected by that part of the heat of a body which is latent. Ice-cold water, and ice itself, feel to have the same temperature, and to contain the same quantity of heat; and yet it is proved that ice-cold water contains a great deal more heat than ice; nay, that it can be compelled to part with its redundant heat, and to become ice; and that this redundant heat, when so dismissed, may be made to boil a considerable quantity of water.* But it is not only in the case of latent heat, which cannot be felt at all, that the touch fails to inform us of the quantities of heat in a body. Different bodies are raised to the same temperature by very different quantities of heat†. If water and mercury, both at the temperature of 32°, be touched, they will be felt to be both equally cold; and if they be both raised to 100° and then touched, they will be felt to be both equally warm; and the inference would be, that equal quantities of heat must have been in the meanwhile communicated to them. Now, on the contrary, it has been proved that, in this case, the quantity of heat which has been communicated to the water is not less than thirty times the quantity which has been imparted to the mercury. In fact, to cause the same change of temperature, and, therefore, the same feeling of heat, in different bodies, requires very different quantities of heat to be imparted to them. It is plain, therefore, that the sense of touch

* Handbook of Nat. Phil.: Heat, § 427, et seq. † Ibid. § 393.

totally fails in the discovery of the quantities of heat which must be added to different bodies, in order to produce in them the same change of temperature.

The thermometer, the scientific measure of temperature, is here, however, in the same predicament as the sense of feeling, since the unequal additions of heat given to the water and the mercury produce precisely the same effects upon it. But even though we omit the consideration of the relative quantities of heat that produce equal changes of temperature in different bodies, the sense of feeling will still be found most fallacious in the indications which it gives of temperature itself; and here, indeed, the error and confusion into which it is apt to lead, when unaided by the results of science, are very conspicuous. The air of a cave, if it be sufficiently deep, will feel cold in summer, and warm in winter. If a thermometer be suspended in it, it will prove that its temperature is always the same. In summer, that temperature being below that of the general atmosphere, the cave feels cold; in winter, being above it, the cave feels warm. The same thermometer which has been kept for sixty years in the vaults of the Observatory at Paris, at the depth of eighty-eight feet below the surface, has shown, during that interval, the temperature of 11°82 Cent., which is equal to 53¼° Fahr., without varying more than half a degree of Fahr.; and even this variation, small as it is, has been explained by the effects of currents of air produced by the quarrying operations in the neighbourhood of the Observatory.

It appears, therefore, that our perception of heat or cold depends not alone on the thermal state of the bodies which affect us, but also on the state of our own bodies at the moment. These perceptions are, in effect, relative, and not absolute. One body feels cold because it is below, and another warm because it is above, the temperature of our own bodies.

It follows, therefore, that if we reduce, by any expedient, different members of our bodies to different states of warmth, any external object which has an intermediate temperature will feel warm to the colder, and cold to the warmer member. This experiment may be easily tried.

If we hold the hands in water which has a temperature of about 90°, after the agitation of the liquid has ceased, we shall become wholly insensible of its presence, and shall be unconscious that the hand is in contact with any body whatever. We shall, of course, be altogether unconscious of the temperature of the water. Having held both hands in this water, let us now remove the one to water at a temperature of 200°, and the other to water at the temperature of 32°. After holding the hands for some time in this manner, let them be both removed, and again immersed in the water at 90°; immediately we shall become sensible of warmth in the one hand, and cold in the other. To the hand which had been immersed in the cold water, the water at 90° will feel hot, and to the hand which had been immersed in the water at 200°, the water at 90° will feel cold. If, therefore, the touch be in this case taken as the evidence of temperature, the same water will be judged to be hot and cold at the same time.

Even when the state of our bodies is the same, and the temperature of external objects the same, different objects will feel to us to have different degrees of heat. If we immerse the naked body in a bath of water at the temperature of 120°, and, after remaining for some time immersed, pass into a room in which the air and every object is raised to the same temperature, we shall experience, on passing from the water into the air, a sensation of coldness. If we touch different objects in the room, all of which are at the temperature of 120°, we shall nevertheless acquire very different perceptions of heat. When the naked foot rests on a mat or carpet, a sense of gentle warmth is felt; but if it be removed to the tiles of the floor, heat is felt sufficient to produce inconvenience. If the hand be laid on a marble chimney-piece, a strong heat is likewise felt, and a still greater heat on any metallic object in the room. Walls and woodwork will be felt warmer than the matting, or the clothes which are put on the person. Now, all these objects are, nevertheless, at the same temperature. From this chamber let us suppose that we pass into one at a low temperature; the relative heats of all the objects will now be found to be reversed —the matting, carpeting, and woollen objects, will feel the most warm; the woodwork and furniture will feel colder; the marble colder still; and metallic objects the coldest of all. Nevertheless here, again, all the objects are exactly at the same temperature, as may be in like manner ascertained by the thermometer.

In the ordinary state of an apartment, at any season of the year, the objects which are in it all have the same temperature, and yet to the touch they will feel warm or cold in different degrees: the metallic objects will be coldest; stone and marble less so; wood still less so; and carpeting and woollen objects will feel warm.

When we bathe in the sea, or in a cold bath, we are accustomed to consider the water as colder than the air, and the air colder than the clothes which surround us. Now all these objects are, in fact, at the same temperature. A thermometer, surrounded by the cloth of our coat, or suspended in the atmosphere, or immersed in the sea, will stand at the same temperature.

A linen shirt when first put on will feel colder than a cotton one, and a flannel shirt will actually feel warm; yet all these have the same temperature.

The sheets of the bed feel cold, and blankets warm; the blankets and sheets, however, are equally warm. A still, calm atmosphere, in summer, feels warm; but if a wind arises, the same atmosphere feels cold. Now a thermometer, suspended under shelter, and in a calm place, will indicate exactly the same temperature as a thermometer on which the wind blows.

815. These circumstances may be satisfactorily explained, when it is considered that the human body maintains itself almost invariably, in all situations, and at all parts of the globe, at the temperature of 96°; that a sensation of cold is produced when heat is withdrawn from any part of the body faster than it is generated in the animal system; and, on the other hand, warmth is felt when either the natural escape of the heat generated is intercepted, or when some object is placed in con-

tact with the body which has a higher temperature, and consequently imparts heat to it. The transition of heat from the body to any object when that object has a lower temperature, or from the object to the body when it has a higher temperature, depends, in a certain degree, on the conducting power of the objects severally; and the transition will be slow or rapid, according to that conducting power. An object, therefore, which is a good conductor of heat, if it have a lower temperature than the body, carries off heat quickly, and feels cold ; if it have a higher temperature, it communicates heat quickly, and feels hot.

A bad conductor, on the other hand, carries off and communicates heat very slowly, and therefore, though at a lower temperature than the body, is not felt to be cold, and, though at a higher temperature, not felt to be warm.

Most of the apparent contradictions which have been already adduced in the results of sensation, compared with thermometric indications, may be easily understood by these principles.

When we pass from a hot bath into a room of the same temperature, the air, though at a higher temperature than our body, communicates heat to it more slowly than the water did, because, being a more rare and attenuated substance, a less number of its particles are in actual contact with the body; and also such particles as are in contact with the body taking almost the same temperature as the body, adhere to it, forming a sort of coating or shield, by which the body is defended from the effects of the hotter part of the surrounding atmosphere. A carpet, being a bad conductor of heat, fails to transmit heat to the foot, and therefore, though at a higher temperature than the body, creates no sensation of warmth. The tiles and marble, being better conductors of heat, and at a higher temperature than the body, transmit heat readily, and metallic objects still more so : these, therefore, feel hot. On passing into a cold room, the very contrary effects ensue. Here all the objects have a temperature below that of the body ; the carpet and other bad conductors, not being capable of receiving heat when touched, produce no sensation of cold ; wood, being a better conductor, feels cooler ; marble, being a still better conductor, gives a stronger sensation of cold ; and metal, the best of all conductors, produces that sensation in a still greater degree.

At low temperatures, the particles of water which carry off the heat from the body are far more numerous than those of air, and therefore withdraw heat more rapidly ; and, besides, they are constantly changing their position ; the particles warmed by the body immediately ascend by their levity, and cold particles come into contact with the skin. Thus water, although a bad conductor of heat, has the same effect as a good conductor, by the effect of its currents.

Sheets feel colder than the blankets, because they are better conductors of heat, and carry off the heat more rapidly from the body ; but when, by the continuance of the body between them, they acquire the same temperature, they will then feel even warmer than the blanket itself. Hence it

may be understood why flannel, worn next the skin, forms a warm clothing in cold climates, and a cool covering in hot climates.

To explain the apparent contradiction implied in the fact that the use of a fan produces a sensation of coolness, even though the air which it agitates is not in any degree altered in temperature, it is necessary to consider that the air which surrounds us is generally at a lower temperature than that of the body. If the air be calm and still, the particles which are in immediate contact with the skin acquire the temperature of the skin itself, and, having a sort of molecular attraction, they adhere to the skin in the same manner as particles of air are found to adhere to the surface of glass in philosophical experiments. Thus sticking to the skin, they form a sort of warm covering for it, and speedily acquire its temperature. The fan, however, by the agitation which it produces, continually expels the particles thus in contact with the skin, and brings new particles into that situation. Each particle of air, as it strikes the skin, takes heat from it by contact, and, being driven off, carries that heat with it, thus producing a constant sensation of refreshing coolness.

Now from this reasoning it would follow that, if we were placed in a room in which the atmosphere has a higher temperature than 96°, the use of a fan would have exactly opposite effects, and, instead of cooling, would aggravate the effects of heat; and such would, in fact, take place. A succession of hot particles would, therefore, be driven against the skin, while the particles which would be cooled by the skin itself would be constantly removed.

It may be objected to some of the preceding reasonings, that glass and porcelain, though among the worst conductors of heat, generally feel cold. This, however, is easily explained. When the surface of glass is first touched, in consequence of its density and extreme smoothness, a great number of particles come into contact with the skin; these particles, having a tendency to an equilibrium of temperature, take heat from the skin, until they acquire the same temperature as the body which is in contact with them. When the surface of the glass, or perhaps the particles to some very small depth within it, have acquired the temperature of the skin, then the glass will cease to feel cold, because its bad conducting power does not enable it to attract more heat from the body. In fact, the glass will only feel cold to the touch for a short space of time after it is first touched. The same observation will apply to porcelain and other bodies which are bad conductors, and yet which are dense and smooth. On the other hand, a mass of metal, when touched, will continue to be felt cold for any length of time, and the hand will be incapable of warming it, as was the case with the glass.

A silver or metallic teapot is seldom constructed with a handle of the same metal, while a porcelain teapot always has a porcelain handle. The reason of this is, that metal being a good conductor of heat, the handle of the silver or other metallic teapot would speedily acquire the same temperature as the water which the vessel contains, and it would be impossible to apply the hand to it without pain. On the other hand, it is usual to place a wooden or ivory handle on a metal teapot. These substances being bad conductors of heat, the handle will be slow to take the temperature of the metal, and even if it do take it, will not produce the same sensation of heat in the hand. A handle, apparently silver, is sometimes put on a silver teapot, but, if examined, it will be found that the covering only is silver; and that at the points where the handle joins the vessel, there is a small

interruption between the metallic covering and the metal of the teapot itself, which space is sufficient to interrupt the communication of heat to the silver which covers the handle. In a porcelain teapot, the heat is slowly transmitted from the vessel to its handle ; and even when it is transmitted, the handle, being a bad conductor, may be touched without inconvenience.

A kettle which has a metal handle cannot be touched, when filled with boiling water, without a covering of some non-conducting substance, such as cloth, or paper, while one with a wooden handle may be touched without inconvenience.

The feats sometimes performed by quacks and mountebanks, in exposing their bodies to fierce temperatures, may be easily explained on the principle here laid down. When a man goes into an oven, raised to a very high temperature, he takes care to have under his feet a thick mat of straw, wool, or other non-conducting substance, upon which he may stand with impunity at the proposed temperature. His body is surrounded with air, raised, it is true, to a high temperature, but the extreme tenuity of this fluid causes all that portion of it in contact with the body, at any given time, to produce but a slight effect in communicating heat. The exhibitor always takes care to be out of contact with any good conducting substance ; and when he exhibits the effect produced by the oven in which he is enclosed, upon other objects, he takes equal care to place *them* in a condition very different from that in which he himself is placed ; he exposes them to the effect of metal or other good conductors. Meat has been exhibited, dressed in the apartment with the exhibitor ; a metal surface is, in such a case, provided, and probably heated to a much higher temperature than the atmosphere which surrounds the exhibitor.

816. **Tactile Sense of Inferior Animals.**—While in man the sensitive functions of the skin are quite as conspicuous as its protective character, these functions in the lower animals are to a great extent sacrificed to the protective influence. The skin, being either incrusted with calcareous matter, or bristling with other epidermic products, becomes the principal, if not the only defensive and protective arm which nature has accorded them.

817. **Fur or Hair** is an epidermic product supplied partly as a protection against external agency, but more as an expedient to preserve the temperature of the body by intercepting the escape of animal heat. It is observed, accordingly, that the fur of animals is richer, thicker, and more abundant as we approach the colder climates. The arctic regions supply all the furs used for clothing and luxury. The hairs, bristles, wool, and feathers, or even the horny and calcareous covering of many animals do not, however, deaden the tactile sensibility as much as is generally supposed ; for these parts severally transmit to the subjacent tissues the impressions

which they receive. They give notice of the presence of bodies, although they produce but very imperfect perceptions of their temperature or volume.

818. **The Organs of the Tactile Sense** are constructed generally in a manner much less favourable to their sensibility than in man. The ape, it is true, is supplied with four hands, while two only are given to man ; but the four hands of the ape, when we come to examine them as instruments of touch and prehension, are incomparably less perfect than the two given to man. The ape can move the fingers separately, but the thumb, much shorter, cannot, as in man, be opposed to the other fingers, and the palmar surfaces, being used for locomotion as well as for prehension, are invested with a callous and comparatively insensible epidermis. In general, the prehensile character of the anterior members, wherever that character remains at all, is more or less sacrificed to the power of sustentation and locomotion. The delicacy of touch so admirable in the human hand is also impaired by other causes. The nails, which in man are so constructed and placed as to increase the tactile power of the finger by serving as a resisting base to its most sensitive part, and giving effect to its pressure upon the object of touch, are, in the inferior animals, converted into hoofs or claws, while the integument surrounding them is either altogether absent from the contact of external objects, or rendered, as just observed, nearly, if not altogether, unserviceable by its use in locomotion. The sensibility, however, thus deadened by the horny substance beneath and around, so far from being extinguished, is accommodated in its intensity to the functions of locomotion, to which the use of the member is confined, so that the animal may have with the foot a distinct perception of the resistance, solidity, and consistency of the ground on which it treads. In these animals, the horny matter of the hoof presses against a derma whose papillary element is very much developed, and which must consequently render sensible the impressions produced upon the member by all the bodies it encounters.

In these classes, also, the lips serve as sensitive organs of touch, being very mobile and abundantly supplied with nerves. In carnivora—as, for example, in the dog—the embouchure of the nasal passage is formed of a tissue divested of hairs, always humid and very sensitive, serving the purpose of the organ of touch.

819. Nothing can be more admirable than the provident care by which nature has supplied the defects of one part by the qualities conferred upon another. In the elephant, the large and ponderous head is supported by a neck endowed with proportionate strength, but necessarily, therefore, thick, short, and inflexible. The animal, unless some other parts were supplied it, would thus be unable to apply its mouth to the ground to collect the vegetable productions which are its proper aliment. The mouth, therefore, ceases necessarily to have any prehensile character or tactile sensibility, and were it not otherwise provided, the animal must soon perish.

Its Creator has therefore furnished it with an extraordinary appendage, consisting of the trunk, a prolongation of the nose so constituted as to be at once an instrument possessing all the requisites for prehensile action, and endowed with the highest degree of tactile sensibility. This trunk is a double tube commencing at the nostrils, of which its two perforations are the continuations. It is lined internally with a fibro-tendinous membrane, surrounded by thousands of minute muscles variously interlaced, and so disposed as to be capable of lengthening or shortening the trunk, and of bending it at will in all possible directions. At its superior extremity there is an elastic and cartilaginous valve, by which the passages from the nostrils are intercepted, but which can be opened by the action of the proper muscles connected with it. By means of this valve and the respiratory mechanism, the trunk is converted into an enormous double syringe, into which liquid can be drawn at will. Thus if the orifices at its extremity be applied to the surface of water, the valve just mentioned being open, and an inspiration made, the air which fills the trunk being drawn towards the lungs, the atmospheric pressure will force the water into the trunk. When it has arisen to the valve, the latter being closed, the water will be retained in the trunk in the same manner as mercury is sustained in a barometric tube. The animal then bending the trunk, thrusts its extremity into its mouth, where it discharges the liquid, which is then swallowed.

By the same principle solid food is collected, the extremity of the trunk acting as a sucker.

To render this instrument of touch and prehension still more effective, it is supplied with an appendage to its extremity in the form of a finger endued with great flexibility.

Animals in general which feed on herbage or other productions placed upon the ground, require that the head should be attached to a neck the length of which is proportionate to that of its fore legs, so that on lowering the head it can apply its mouth to the ground without bending the legs. These conditions are obviously incompatible with a large and ponderous head like that of the elephant, and we accordingly find animals, such as the giraffe, having fore legs of considerable length, and consequently a neck in proportion furnished with a small and light head.

820. All animals are furnished with instruments of prehension, having an obvious relation to the nature and locality of their aliment. Thus, those which feed on roots, and are consequently obliged to seek their proper aliment by digging into

the earth, are supplied with trunks, not like that of the

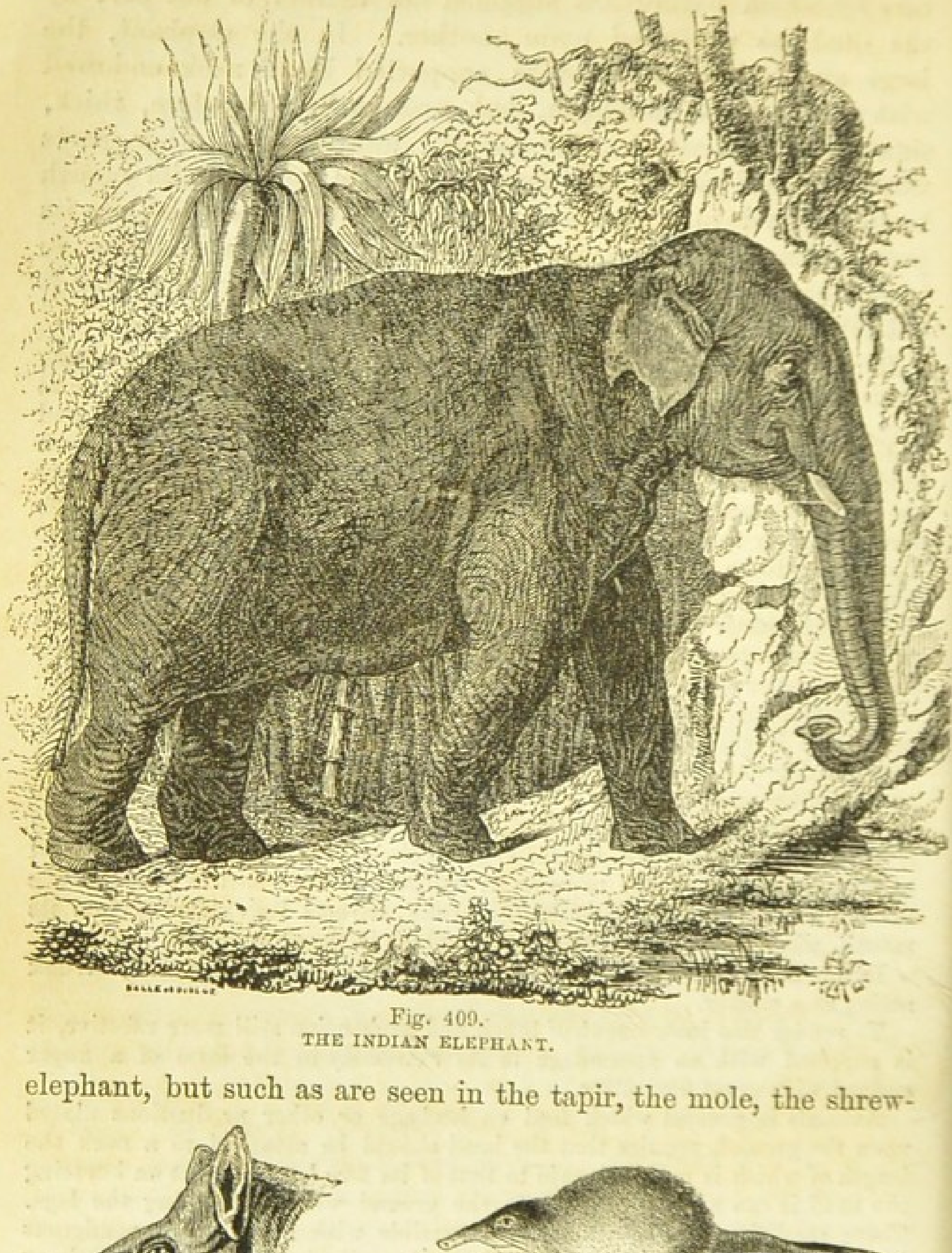


Fig. 409.
THE INDIAN ELEPHANT.

elephant, but such as are seen in the tapir, the mole, the shrew-

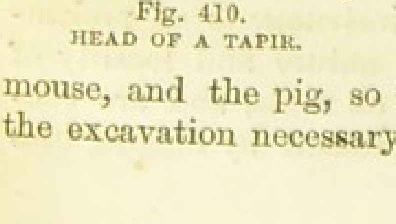


Fig. 410.
HEAD OF A TAPIR.

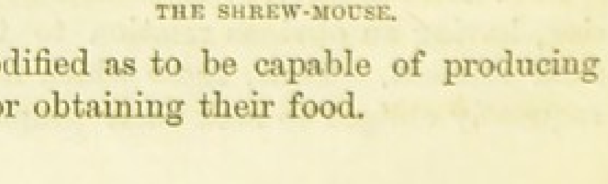


Fig. 411.
THE SHREW-MOUSE.

mouse, and the pig, so modified as to be capable of producing the excavation necessary for obtaining their food.

821. Some animals are supplied upon the upper lip with large and stiff hairs, capable of being moved by muscles attached to their bases, which transmit the impression they receive to the sensitive tissues in which they are implanted.

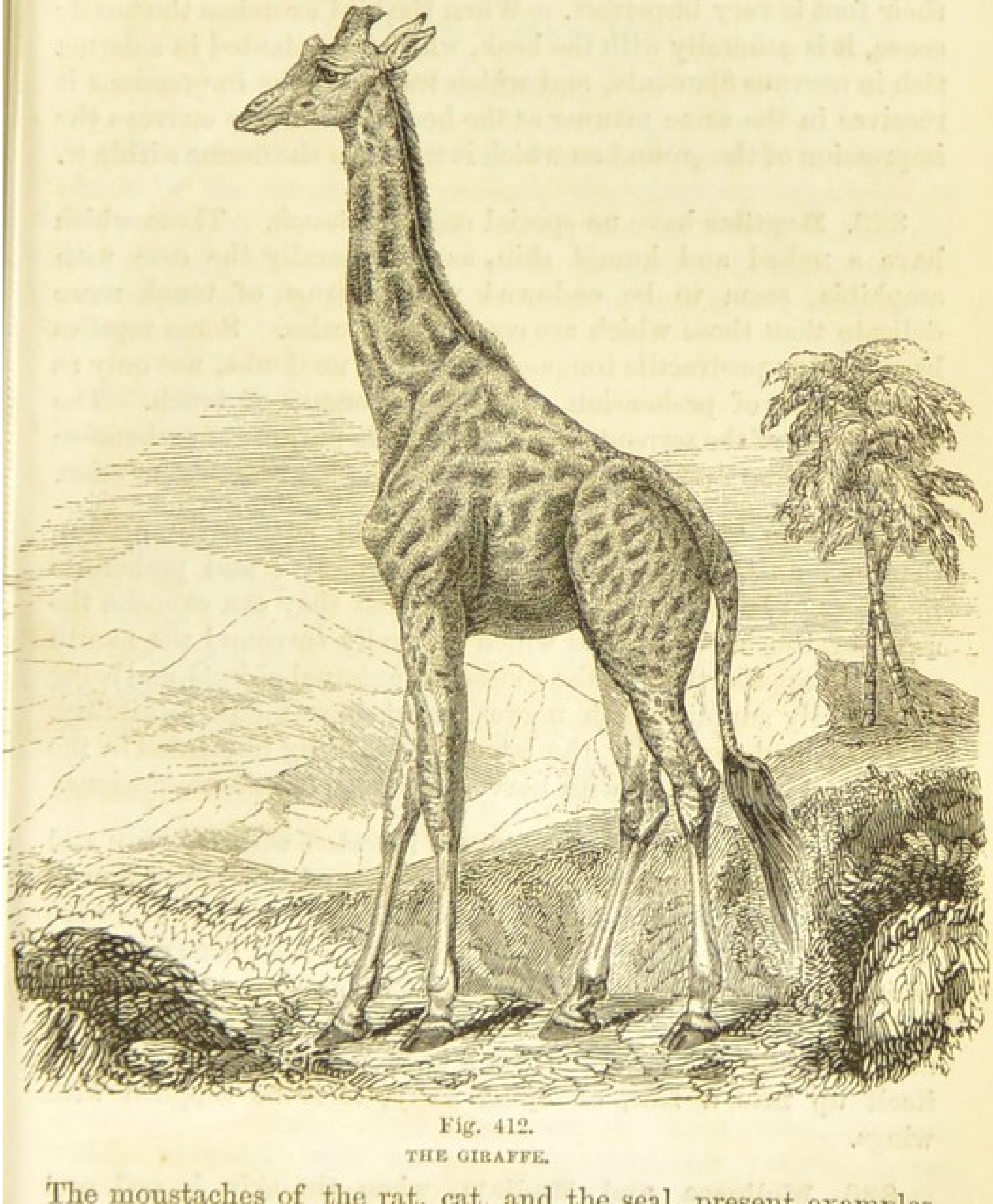


Fig. 412.
THE GIRAFFE.

The moustaches of the rat, cat, and the seal, present examples of this. The bristles of the hedgehog and the quills of the porcupine serve, in the same manner, to apprise the animal of the contact of external objects.

822. **Birds** covered with feathers, whose anterior members

are transformed into wings, have feet covered with scales upon their dorsal surface, coated on their inferior surface with a skin poorly supplied with nerves, and covered with a thick and somewhat insensible epidermis. Their touch, therefore, with their foot is very imperfect. When the bird exercises the tactile sense, it is generally with the beak, which is implanted in a derma rich in nervous filaments, and which transmits the impressions it receives in the same manner as the hoof of the horse conveys the impression of the ground on which it treads to the derma within it.

823. **Reptiles** have no special organ of touch. Those which have a naked and humid skin, as is generally the case with amphibia, seem to be endowed with a sense of touch more delicate than those which are coated with scales. Some reptiles having very protractile tongues, use them, no doubt, not only as instruments of prehension, but also as organs of touch. The entire body of the serpent serves the double purpose of prehension and touch, the animal rolling itself round what it desires to seize.

824. **The Tactile Sense of Fishes** is necessarily obtuse, deprived as they are of the usual locomotive and prehensile members. It is only by their lips that they can exercise the sense of touch. The barbs which generally surround the mouth probably apprise them of the contact of external objects, and being abundantly supplied with nerves, must have tactile sensibility. The fins, and especially the lateral ones, being implanted in the flesh, and surrounded with nerves, transmit tactile impressions.

825. **Annulata and Crustacea**, invested with a horny and calcareous envelope, are rendered sensible of the impression of external objects by the whole surface of the body. They are supplied also generally on either side of the head with antennæ, which enjoy a highly delicate sensibility, and are thence called *feelers.* When these appendages encounter any object, the animal betrays its sensibility by a sudden motion, either rolling itself up into a ball, or flying away, if it be supplied with wings.

826. **Mollusca and Radiata**, when the skin is soft and humid, which is mostly the case, have an obtuse sensibility diffused over the whole body. Some, such as the cephalopods, the polypes, the hydra, &c., are supplied with arms, or tentacula, endowed with special tactile sensibility.

CHAPTER XIII.

THE SMELL.

827. **Structure of Olfactory Organ.**—Placed at the embouchure of the respiratory passage, the olfactory apparatus is endowed with the faculty of testing the air which enters the lungs, being affected with a peculiar sensation, agreeable or the reverse, according as that fluid is pure or impure, noxious or innoxious.

828. **Nasal Fossæ.**—To render the sensitive membrane of this organ the more efficient, it has been in all cases so constructed as to expose the greatest possible surface within the least possible space to the contact of the air in its passage to the trachea. This is accomplished in the human organism by giving to the passages called the *nasal fossæ* the form of two narrow cavities, separated by a thin partition, called the *septum narium*, lying in the median plane of the nose. Each of these cavities is bounded by two walls: the internal, formed by the side of the septum narium, is flat and nearly vertical, consisting partly of bone (the ethmoid and vomer), and partly of the nasal cartilage. The external wall is much more uneven, consisting of three principal arched and convoluted bones, called the *superior*, *middle*, and *inferior spongy*, or *turbinate bones*, which are bounded and separated by three depressions or channels, called the *superior*, *middle*, and *inferior meatuses*.

829. **Pituitary Membrane.**—These walls are covered with a fibro-mucous coating, called the *pituitary membrane*, from its faculty of secreting a viscous liquid, with which its surface is constantly covered. This membrane is highly vascular, and richly supplied with nerves. Its thickness varies; being greatest where most exposed to the contact and friction of the passing currents of air. Thus, it is thickest over the turbinate bones, and especially over the inferior one, where the air first encounters it, and upon which it forms projections which have the effect of increasing the extent of its surface. On the septum narium, forming the inner wall, it is also very thick and

spongy; but in the intervals between the turbinate bones and the floor of the nasal fossæ, where it is less exposed, it is much thinner.

830. **General Description of the Organ.**—This description will be rendered easily intelligible by reference to fig. 413, representing the outer wall of the left fossa, and fig. 414, representing the inner wall of the right fossa. In fig. 413, the pituitary membrane is shown, and in fig. 414, the nerves which are distributed through it.

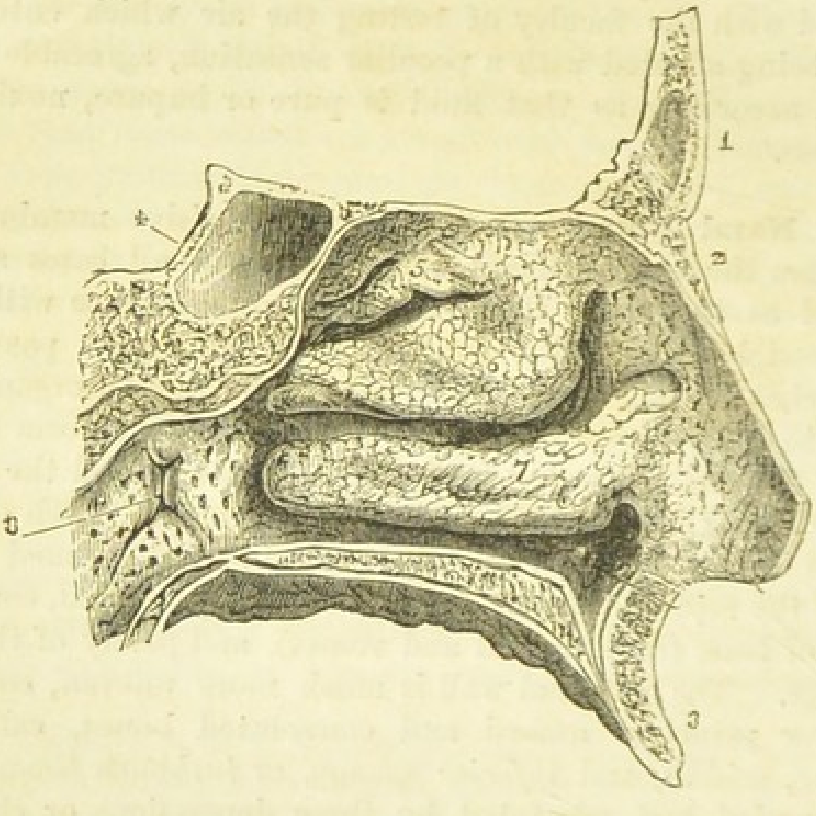


Fig. 413.

EXTERNAL WALL OF LEFT NASAL FOSSA, COVERED WITH THE PITUITARY MEMBRANE (Quain).

1. Frontal bone.
2. Nasal bone.
3. Superior maxillary.
4. Sphenoid.
5. The upper spongy bone.
6. Middle spongy bone.
7. Lower spongy bone—the three meatuses of the nose are seen below the three last-named bones.
8. The opening of the Eustachian tube.

831. **Nerves of Olfactory and Tactile Sensibility.**—The pituitary membrane is endowed with two distinct species of sensibility: special and general; or, the olfactory and the tactile. These distinct nervous functions were first demonstrated by Willis, who showed that the olfactory power resided in the nerves of the first pair, the origin of which is shown at 244[22],

while the tactile faculty is limited to those of the fifth pair, or trifacial nerves, the origin of which is shown in 244[27]. This capital distinction, the validity of which was long disputed, has been clearly established only within the last twenty years. The principal arguments which determined the exclusive

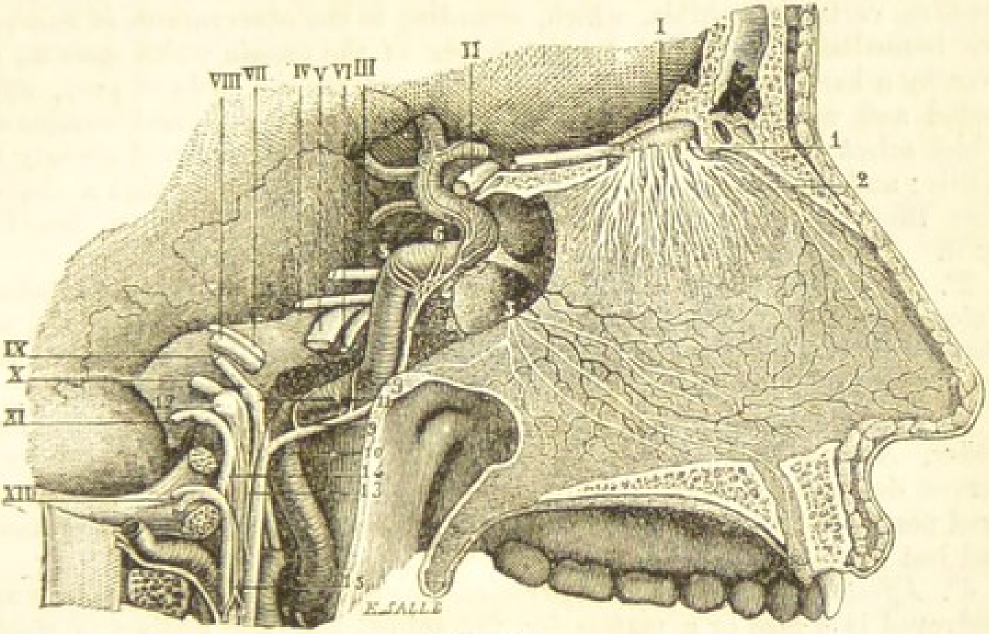


Fig. 414.

NERVES WHICH ARE DISTRIBUTED UPON THE INTERNAL WALL OF THE RIGHT NASAL FOSSA, INCLUDING THE CAROTID BRANCHES OF THE GREAT SYMPATHETIC (Sappey).

1. Terminal branches of the olfactory nerves.
2. Internal divisions of the ethmoidal filament of the nasal branches of the ophthalmic nerve.
3. Naso-palatine nerves.
4. Cavernous plexus of the carotid branch of the great sympathetic, presenting at this point a gangliform appearance.
5. Nervous filaments proceeding from this plexus to Gasser's ganglion, to the ophthalmic branch, to the common motor of the eye, and to the pathetic.
6. Filaments which proceed from the same plexus to the external motor of the eye.
7. Ramifications supplied by the carotid branch to the divisions of the carotid artery.
8. Internal filament of the carotid branch.
9—9. Filaments communicating between the internal and external parts of the carotid branch.
10. External filament of this branch disappearing almost immediately behind the carotid artery.
11. Enlargement of the glosso-pharyngeal nerve.
12. Trunk of the pneumo-gastric nerve.
13. Filament uniting the glosso-pharyngeal and pneumo-gastric nerves with the carotid branch.
14. Filaments uniting the spinal accessory with the pneumo-gastric.
15. Filament uniting the great hypoglossal with the carotid branch.

I. Pedicule and ganglion of the olfactory nerve.
II. Optic nerve.
III. Common motor of the eye.
IV. Pathetic.
V. Trigeminal.
VI. External motor of the eye.
VII. Facial.
VIII. Auditory.
IX. Glosso-pharyngeal.
X. Pneumo-gastric.
XI. Spinal accessory.
XII. Hypoglossal.

olfactory character of the nerves of the first pair are the following :—

1°. *Facts drawn from Comparative Anatomy.*—The animals in which these nerves are most developed are those endowed with the strongest instincts of scent. Among the fishes may be mentioned sharks, which collect from a great distance round bodies thrown into the sea ; among the reptiles, certain amphibia, which, according to the observations of Scarpa, are immediately attracted by the odour of the female which spawns, or even by a hand rubbed upon her spawn ; among the birds of prey, web-footed and waders ; and, in fine, among the mammifers and ruminants which select their aliments by the smell, as has been observed already by Willis ; and carnivora, which have the faculty of scent in so high a degree that they seek their prey in places which have long been deserted by it.

2°. *Facts drawn from Abnormal Anatomy.*—Schneider, Haller, Valentin, Rosenmüller, Cerutti, Pressat, and others, have ascertained the absence of olfactory nerves in individuals who have been deprived of the sense of smell from their infancy.

3°. *Facts derived from Pathological Anatomy.*—Morgagni, Baillou, Loder, Appert, Leblond, Vidal, and others, have found the olfactory nerves destroyed, compressed, or more or less altered, with adults and aged persons who, after having enjoyed the sense of smell to a late period, had lost by degrees this faculty.

4°. *Effects derived from Experiments.*—When the olfactory nerves are destroyed in a bird or a mammifer, the animal loses the instinct of smell. If, by the aid of a tube, we direct an odoriferous current towards the parts of the pituitary membrane on which the olfactory nerves are distributed, the impression of the odour is strongly felt. If the current is directed to any other part of the membrane, the impression ceases.

832. **Conditions of Sensibility.**—It appears from these and many other circumstances that the nerves of the first pair are properly and exclusively olfactory, but that their power is intimately connected with other conditions of the pituitary membrane. Thus, to render them efficient, the secretions of which that membrane is the seat must neither be suppressed, unduly augmented, nor altered. Now, these secretions, as well as the tactile sensibility of the membrane, are placed under the influence of the trifacial nerves, or those of the fifth pair, which, consequently, are endowed with functions upon which the exercise of smell indirectly depends, although they do not participate in any manner in the transmission of the odorous impressions to the sensorium.

833. **Pituitary Glands.**—Each organ of sense is supplied with its proper glands, which secrete a humour peculiar to it. Thus, the organ of hearing has the ceruminous glands ; that of vision the lachrymal glands ; that of taste the salivary glands ;

and that of touch the sudoriferous glands. The olfactory organ is in like manner richly furnished with the *pituitary glands*, which, as their name imports, are formed in the pituitary membrane. These glands maintain, in a state of permanent humidity, the free surface of the pituitary membrane, lubricating it with the peculiar mucous fluid which they secrete. In this fluid the odorous molecules are dissolved, and, in solution, affect the olfactory nerves in the same manner as the gustatory nerves are affected by sapid molecules dissolved in the saliva. Although solid matter finely pulverised may excite the pituitary membrane, such effects are merely tactile, and not at all olfactory. Thus, snuff, when taken, irritates the tactile nerves, and does not necessarily affect the olfactory.

834. **The Secretion of these Glands** is essential, though in an indirect manner, to the exercise of the olfactory sense. When the secretion of mucus is suspended, the sense of smell ceases.

835. **Close Relation between Smell and Taste.**—This is admitted by all physiologists, and it has even been maintained by some that smell is nothing more than a modified taste. This opinion was, I believe, first advanced by Kant. It is rejected by Müller, but has been recently reproduced and sustained by other physiologists, and more especially by M. Brillat-Savarin, in his work on the physiology of taste.

It is contended by the partisans of this doctrine, that without the concurrence of smell there can be no real gustation. The smell and taste, according to M. Brillat-Savarin, constitute a single sense, of which he says the mouth is the laboratory and the nose the chimney. According to that physiologist, the gustatory organs of the mouth have no sense of taste except for bodies in the liquid state, to which all sapid ones which are solid are reduced by solution in the saliva ; but bodies in the gaseous or vaporous state are tasted only by the pituitous membrane, and their taste is called by the name of *smell.*

836. M. Brillat-Savarin supports this doctrine principally upon the three following facts :—

1°. That when the nasal membrane, being affected by a violent cold, is deprived of its coating of mucus, the taste is entirely obliterated, no savour is perceived upon any substance which is taken into the mouth, although the tongue remains in its natural state.

2°. If we stop the nose in eating, all perception of taste becomes obscure and imperfect ; and accordingly this expedient is commonly adopted in swallowing disagreeable medicines.

3°. The same effect is produced at the moment of swallowing any substance, if, instead of allowing the tongue to return to its natural position, it is kept pressed upon the palate of the mouth. In that case the circulation of air through the nasal fossæ is stopped, the sense of smell suspended, and we are conscious of no perception of taste.

837. **Odours.**—Certain bodies have the property of exhaling effluvia, by which those peculiar olfactory sensations are excited which are expressed by such terms as scent, perfume, fragrance, stench, and so on. Although bodies easily volatilised or vaporised are placed under conditions favourable to the production of such impressions, it is neither true that such bodies are always odorous, nor that bodies not volatile or vaporisable are not so. Many gases—atmospheric air, for example—are inodorous ; and the metals, the least volatile of bodies, emit effluvia having peculiar odours. Every one is familiar with the smell of a workshop in which iron, brass, or copper is wrought.

In general, the effluvia by which odorous bodies affect the smell are so subtle as entirely to escape physical and chemical analysis. A piece of tobacco, a grain of assafœtida or musk, or even a paper in which any of these substances have been wrapped, will scent a large room. It is even said that a grain of musk will continue for years to impregnate the atmosphere of a well ventilated room, without suffering any perceptible decrease of weight.

To reduce the intensity of odours to numerical measure is extremely difficult, since, as has been stated, they escape all physical and chemical tests, and defy all re-agents less perfect than the organic membrane of the nose. It has, therefore, been proposed to measure at least the minor limits of their olfactory power by dissolving odorous substances in given quantities of pure air, water, or other inodorous medium, and by gradually increasing the proportion of inodorous matter to render the solution weaker and weaker, until the odour becomes imperceptible. In this manner, odours may be grouped and tabulated according to their intensities. It is true that the same odorous solution will affect different individuals differently, according to the acuteness of their organs, but this will not prevent a *relative* scale being determined. The relative sensibility of the olfactory organs of different individuals may also be ascertained, by finding the relative degrees of dilution at which certain odours become imperceptible to them.

Sulphuretted hydrogen, a very offensively smelling gas, is

perceivable when a single cubic inch is mixed with half a million cubic inches of atmospheric air.

838. Bodies are more or less susceptible of being impregnated with odorous effluvia. Those which are most capable of retaining such effluvia are such as are most porous, and capable of receiving and retaining air in their interstices, or from their fluidity and affinity for air are capable of being mixed with it. Thus, clothing, wood, and water will acquire the odour of bodies to which they are severally exposed, while glass will not do so. If musk, or the attar of roses be enclosed in a glass bottle, with a close stopper, the effluvia will not penetrate or impregnate the glass, and the surrounding air will be exempt from the scent of these substances ; but if enclosed in a wooden bottle, their smell would soon be perceptible.

When the air, impregnated with odorous effluvia, passes through the nasal fossæ, it appears to be strained of the effluvia in the same manner as the gases of combustion proceeding from the furnace of a steam-engine are strained of their heat in passing through the flues of the boiler, since no sense of odour attends the air which is expired. If, however, the nose being stopped with the fingers, odoriferous air be inspired with the mouth, and then the mouth being closed it is expired by the nose, the peculiar odour is perceived in such expiration, though not so strongly as if the air were originally inspired by the nose. This comparatively diminished intensity of the odour may arise either from the peculiar form and effect of the mechanism of expiration compared with inspiration, or from the partial dissipation of the odorous effluvia in the trachea, bronchi, and lungs.

839. **Impact on Pituitary Membrane.**—It would seem as though the olfactory nerves were excited by the impact of the odorous molecules, rather than by their mere contact with the pituitary membrane. When we scent a flower, we make a quick succession of inspirations, holding the flower under the nose ; and the pointer who scents the ground is observed to exercise the same respiratory action. Now, it cannot be doubted, that the air in passing through the nasal fossæ deposits on the pituitary membrane, dissolved in the mucus which covers it, more or less odoriferous molecules ; and if the mere contact of these were sufficient to excite the olfactory nerves, it might be expected that on stopping the nose, after a full inspiration of odorous effluvia, the sensation of the odour would be continued

at least for a certain interval. This, however, is not found to be the case, the cessation of the consciousness of the scent being simultaneous with the completion of the act of inspiration.

840. **Smell soon deadened by Excess.**—No sense is so soon rendered obtuse by excitement as the smell. Every one knows how soon we become unconscious of the most agreeable perfumes on the one hand, and of the most offensive smells on the other. Those who habitually use scents, being themselves wholly insensible to them, are reasonably enough suspected of resorting to them to disguise from others disagreeable personal emanations.

This also explains why persons affected with fœtid breath are unconscious of it, while those who by eructation expel offensive gases from the stomach perceive them if the mouth be closed. The former are not sensible, because respiration is continual, and the latter is perceived, because the eructation is only occasional.

841. **The Nostrils,** although not directly endowed with olfactory sensibility, are nevertheless subservient to the sense of smell by giving such a direction to the respiratory current, as to propel it along the walls of the fossæ. In the case of persons who have lost the nose, the current, following the shortest route, passes chiefly along the floor of the fossæ, coming but little in contact with the walls, and thus escaping, in a great degree, the pituitary membrane, which is the more especial organ of smell. In such cases, the olfactory functions are re-established by an artificial nose.

When we desire to excite in a great degree the sense of smell, we close the mouth, so as to draw the respiratory current exclusively through the nose. On the contrary, to avoid a disagreeable odour, we stop the nostrils and respire exclusively through the mouth. The same purpose, however, may be in a great degree attained, by keeping the mouth open without stopping the nostrils, because by so doing respiration takes place chiefly by the mouth, and very little by the nose. The air in the nasal fossæ, therefore, being scarcely changed, there is but little exercise of the sense of smell.

842. **Different Susceptibility of Smell.** — Different individuals are differently affected by particular odours, according to the varying condition and susceptibility of their nervous system. Many odours perceivable by some are totally unperceived by others ; such, for example, as the scent of violets, mignonette,

and some other flowers. This difference of susceptibility is still more striking when man is compared with animals, many of which are strongly sensible of scents of which we are totally unconscious. Thus the dog tracks his master over ground upon which other individuals have subsequently passed, being, therefore, not only capable of perceiving the *general* scent of man, but of distinguishing the *special* scent of one particular person.

Odours which are agreeable to some are offensive to others. Musk and assafœtida are examples of these. The repugnance of some persons to musk is such as to produce syncope. Many perfumes agreeable to some produce megrim, nausea, and swooning in others.

843. **Subjective Olfactory Sensations** are less common and less understood than the corresponding illusions of sight and hearing. They are rare in some persons, but not uncommon with those afflicted with mental derangement, having their origin evidently in cerebral disturbance. Thus, insane patients often complain that fœtid or fæcal matter has been mixed with their food.

844. **The Direction of Odorous Objects** cannot be at all determined by the organ of smell, as that of visible and audible objects is by the organs of seeing and hearing. When odours are brought within the perception of the sense by currents of air, the directions in which they lie are determined not by the olfactory organ, but are judged of by the mind, which imputes their transport to the aërial current, and identifies their direction with the direction of that current.

845. **The Olfactory Sense of Inferior Animals. Mammifers** have generally this sense more developed than man. In ruminants, carnivora, and rodents, the pituitary membrane is relatively much more extensive, and has a structure which gives it a greater surface within a given space.

846. **Birds** do not exhibit much development of the olfactory organs. The olfactory lobes of the cerebrum, from which the nerves of smell proceed, are, however, considerably developed. This is observable more especially in predaceous and piscivorous birds. Notwithstanding this, birds do not seem to be endowed with great delicacy of smell, discovering their prey in general by the sharpness of their vision.

847. **Reptiles** have nasal cavities, consisting of two canals, opening outwards by nostrils and communicating with the mouth by two holes in the vault of the palate. In the case of naked reptiles the nasal canals are merely lined with mucous membrane. In that of scaly reptiles, the turbinate bones are more or less developed. The olfactory nerves have, in general, considerable volume, and are conducted to the nostrils by a special bony and cartilaginous canal, formed for them in the bones of the skull.

848. **Fishes**, inhabiting the water, are supplied with an olfactory apparatus suitable to that fluid, and consisting of two small cavities in a cul-de-sac, opening outwards by two nostrils. The bottom of these sacs generally consists of folds, sometimes grouped radially with a central part, and sometimes arranged like the leaves of a book. These sacs receive filaments of the olfactory nerve proceeding from the cerebral lobe. The water which imparts odours to the olfactory membrane cannot be so freely and frequently renewed as in the case of animals which respire in the air, for there is here no continuous current, properly speaking, the water being ejected from the opening at which it is admitted. The sense of smell in this class must therefore be very imperfect.

849. **The Annulata, Mollusca, and Radiata,** appear to be endowed with no special organ of smell. It is certain, nevertheless, that some of these, and more particularly insects, are not altogether deprived of this sense. Flies, bees, and gnats, are attracted from a distance by honey, sugar, meat, and other objects which supply their nourishment. Some physiologists think that it is in the antennæ or tentacula that the faculty of smell resides.

Cuvier, however, was of opinion that the olfactory sense of insects was exercised by the stigmata placed at the embouchures of their tracheæ, or organs of respiration.

CHAPTER XIV.

TASTE.

850. **The Tongue.**—Although the tongue be the principal organ of taste, other parts of the mouth co-operate directly and indirectly in the exercise of that sense. Neither are all the parts of the tongue itself sensible of gustatory impressions, nor are those which are so, equally sensitive to them.

The mucous membrane of the tongue is supplied with numerous papillæ unequally distributed, having very different forms and, apparently, gustatory and tactile properties with corresponding differences. It is also richly supplied with blood-vessels and nerves, and is composed of a mass of muscles and nerves, which give it that infinite mobility so necessary to speech, and the processes of mastication and insalivation.

851. **Various Experiments** have been made to determine the parts of the mouth which are more or less endowed with the gustatory sense, but hitherto no very definite results have been obtained. Such researches are attended with many difficulties. The organ can only be excited by sapid matter in a state of solution. If the substance under experiment be solid, it must therefore be soluble in the saliva, and when thus liquified, it has a tendency to diffuse itself over parts of the mouth to which the experiment is not addressed.

Expedients have been contrived therefore to localise the action of the sapid matter. Messrs. Pernière, Panizza, and others, used small sponges impregnated with the sapid solution, and attached to the extremities of whalebone rods. They also, in certain cases, supported the solution in capillary tubes, applying their extremities to the part under trial. Messrs. Guyot and Admyrault enclosed the tongue in a glove of softened parchment, in which a hole was made corresponding in its position to the part whose gustatory sensibility was to be tried.

In all such arrangements, however, the taste is exercised under abnormal and unnatural conditions, and the results, whatever they may be, are unsatisfactory and inconclusive. In

natural gustation the tongue is applied with a certain degree of friction against the palate, and the universal consciousness of the concurrence of this latter part in the exercise of taste is indicated by the familiar use of the term palatable.

It seems to be generally agreed that the principal seat of the sensation of taste is near the root, or what anatomists call the *base* of the tongue, that is, the part of the tongue which is attached to the posterior part of the mouth; but it is also demonstrated that the upper part of the pharynx and the lower part of the pillars of the veil of the palate participate in the gustatory sensibility. Most physiologists deny to the lips, gums, cheeks, dorsal, or upper surface of the tongue, and the vault of the palate any sapid sensibility. Whether the point of the tongue, its borders, its inferior surface, or the membranous part of the vault of the palate are sensible to taste, is disputed.

In all investigations directed to the solution of this class of physiological problems, it must never be forgotten that alkaline, acid, astringent, and acrid principles affect the tactile and not the gustatory sensibility. Sapid substances of a saccharine, salt, or bitter flavour produce no sensation of taste when applied exclusively to the point, borders, or inferior surface of the tongue. If these parts be sensible to taste at all, it can only be to those whose action upon the gustatory nerves is one of extreme intensity.

When a sapid substance is deposited upon the parts of the tongue which are admitted to be endowed with gustatory sensibility, the taste is not excited in any considerable degree until the mouth has been closed, and the tongue pressed and rubbed against the palate. It does not necessarily follow that in this case the palate itself is sensible to the taste; but the application of the tongue compresses the gustatory papillæ, and increases the action of the sapid matter upon them by friction, and thus excites in a greater degree, the sensation of taste.

852. In deglutition and mastication, the sapid principles of the food are made to act upon the various sensitive parts of the mouth, so as to excite gustation. Mastication, by the repeated friction which attends it, and the incessant play of the tongue, and all the softer parts, especially stimulates the sense of taste. The aliment being dissolved in the saliva is also reduced to a condition more favourable to the excitement of gustation.

A long-continued and repeated contact of the sapid matter is necessary to the full development of the sense of taste. The wine-taster judges of the quality of the liquor under trial by

moving it round all parts of his mouth repeatedly, and allowing it to remain in contact with those parts most strongly endowed with gustatory sensibility before he swallows or ejects it.

853. **Limit of Gustatory Sensibility.**—The organ of taste is infinitely less sensitive than that of smell, as may be rendered evident by comparing the relative strength of the solutions which affect the two senses.

If a grain of sugar be dissolved in a hundred grains of pure water, no degree of sweetness will be perceived in the solution. If a grain of common salt be dissolved in two hundred grains of water, the solution will be also destitute of all sensible saltness. The solutions of certain bitter or sweet principles, such as strychnine or salt of silver, are sensible to taste, it is true, at a very inferior degree of strength ; but, even in these, the proportion is infinitely below those by which, as already explained, the sense of smell is strongly affected.

Colocynth is, as is well known, a strong bitter ; but if a grain of it be infused in 5000 grains of water, its peculiar flavour will not be perceived.

854. **Delicacy of Taste varies.**—The sense of taste varies extremely in different individuals, as may be seen in the different degrees of enjoyment they receive from the pleasures of the table. Some individuals seem almost indifferent to the nature and qualities of their aliment. Many are so regardless of this, that they scarcely know the difference between beef and mutton. Others, on the contrary, regard the act of eating as one of the chief pleasures of life. Such immoderate enjoyment of the table must not, however, be exclusively ascribed to the greater sensibility of the taste, since much, no doubt, depends upon the delicacy of the olfactory sense which, as already explained, is so closely connected with the sense of taste.

855. **Experiments** which are more or less familiar to every one, demonstrate this close connection of the two senses.

We are enabled with great facility to perceive the quality—good or bad —of various kinds of food, such as meat, fish, butter, milk, or bread ; but if these be tasted and masticated, with the nose stopped and the eyes bandaged, no perception of the goodness or badness of their qualities will be produced. In such cases we do not easily distinguish, for example, wine from water, and most aliments lose their peculiar taste. It is only very strong gustatory qualities, such as those of salt and sugar, that are perceptible.

856. **Papillary Structure of the Tongue.**—Papillæ (780), found on all parts of the tegumentary integument of the

body, internal as well as external, being the more immediate seat of sensibility, it may be expected that the mucous membrane of the tongue, endowed as it is in so eminent a degree with both tactile and gustatory sensibility, should exhibit a papillary structure of peculiar richness.

Anatomical observation, more especially when seconded by the powers of the microscope, fully verifies this anticipation. All parts of the surface of the tongue are thickly covered with papillæ, but these are not uniformly distributed, nor are they similar in form or magnitude.

857. **Dorsal Surface of Tongue.**—It is on the superior surface, or *dorsum* as the anatomists call it, that the papillæ prevail in the greatest numbers. A view of the dorsum is given in fig. 415, from the work of Professor Sappey, which is by far the most accurate and elaborate representation of the organ which I have seen.

That anatomist classes the lingual papillæ in four orders called Calyciform, Fungiform, Corolliform, and Hemispherical.

858. 1°. **Calyciform Papillæ.**—The first in order, and largest in their dimensions of the lingual papillæ, are disposed in the form of the legs of the letter A upon the upper surface of the tongue, the point of junction of the legs being directed backward, and holding a position in the middle of the breadth of the tongue, at a part about three-fourths of its entire length, from the anterior extremity, or tip. These are shown converging from 415^1 to 415^2.

The number of these papillæ of the first order, varies from eight to fourteen or fifteen.

Each of these has the form called in geometry that of a truncated cone, that is, a cone with its point cut off. The smaller end of the cone forms the base of the papilla, and the greater end is level with the general surface of the tongue. The papilla is implanted in a cup-like cavity surrounded with a circular furrow or trench, outside which is a circular ridge rising to the level of the upper surface of the papilla.

The whole resembles that of the crater of a volcano, if its central cone be conceived to be inserted so as to stand upon its blunted apex.

This class of papillæ has been called by some anatomists *vallatæ*, or *circumvallatæ*, from the circumstance of being surrounded by a trench. They are also called *calyciform*, from the circumstance of standing within a cup.

859. **Foramen Cæcum.**—At the point of the A is a part (415^2) called the *foramen cæcum*, described by the older anatomists as the excretory duct of a salivary gland, and by Quain, Wilson, and other English elementary writers, as the embouchures of several mucous glands or follicles. Some foreign anatomists, however, and Professor Sappey in particular, affirm this to be an error, and describe it as the largest of the calyciform papillæ, being sometimes single, but often consisting of two or more papillæ included within a single calyx.

860. 2°. **Fungiform Papillæ.**—In front of the papillæ here described, and occupying the middle third of the length of the tongue, are found numerous

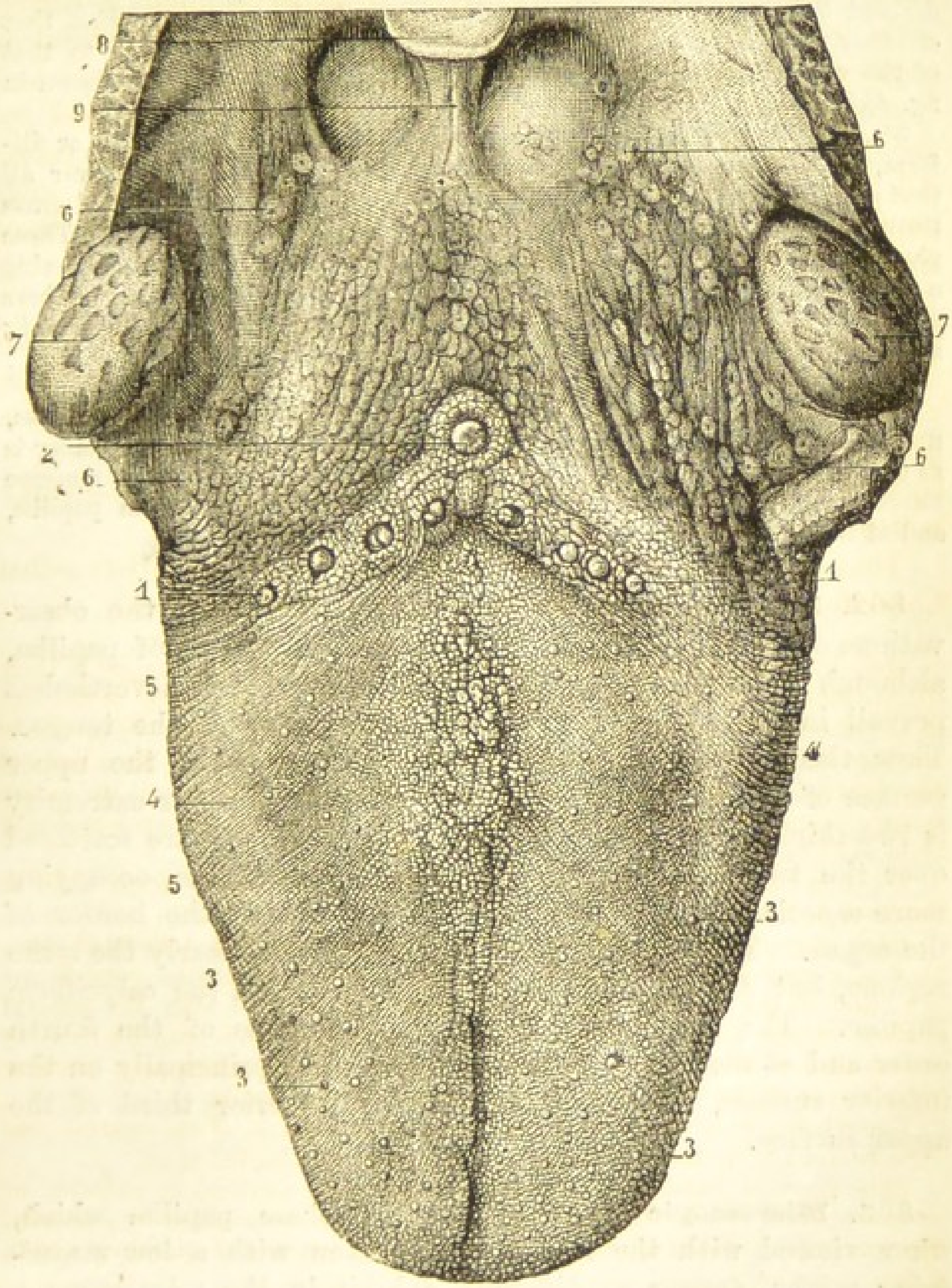


Fig. 415.

DORSAL SURFACE OF THE TONGUE, SHOWING ITS PAPILLARY STRUCTURE (Sappey).

others, much less voluminous, but more numerous and more closely packed together, like the pile of velvet. These stand perpendicular to the lingual surface, and are not inclined backwards, as was maintained by Malpighi. They are generally arranged in parallel lines emerging from the

axis of the tongue as branches emerge from the stem of a leaf. These papillæ have generally a form resembling that of a mushroom, being expanded at the summit and contracted at the base, whence they have derived the name of *fungiform*. Their magnitude is greater than that of other papillæ by which they are surrounded, but very inferior to that of the calyciform above described. These fungiform papillæ are shown in fig. 415 [3].

3°. The **Corolliform Papillæ** called also conical, cylindrical, or filiform, by most anatomists, are smaller than the fungiform, and cover all that part of the tongue in front of the calyciform with a sort of tufted grass through which the particles of sapid liquids diffuse themselves. These papillæ have very various dimensions and forms. Some are filiform, having a uniform diameter; others, being larger at the base, are conical. Others are more or less oval in their transverse section; others are quite flat; and, in fine, some are prismatic, triangular, pyramidal, &c.

861. 4°. **Hemispherical Papillæ.**—These are of extreme minuteness, not exceeding those of the last phalanges of the fingers. Their number is so great as to be incapable of any calculation. They prevail in immense numbers in the intervals between the fungiform and corolliform papillæ, and at the bottom of the trenches which surround these.

862. **Distribution of Papillæ.**—It appears from the observations of Professor Sappey that these four orders of papillæ, although to a certain extent mingled together, nevertheless prevail in greatest numbers at particular parts of the tongue. Thus the calyciform are limited to that part of the upper surface of the tongue whose distance from the anterior extremity is two-thirds of the entire length. The fungiform are scattered over the two anterior thirds of the upper surface, occupying more especially the tip and the anterior half of the border of the organ. The corolliform papillæ prevail in nearly the same regions, but exist also in a little group behind the calyciform papillæ. The hemispherical papillæ, or those of the fourth order and of the greatest minuteness, prevail principally on the inferior surface, lateral parts, and the posterior third of the upper surface.

863. **Microscopic Appearance.**—All these papillæ which, when viewed with the naked eye or even with a low magnifying power, appear so different, exhibit in the microscope a remarkable analogy of structure. The calyciform, fungiform, and corolliform papillæ are, according to the observations of Professor Sappey, nothing more than different agglomerations of hemispherical papillæ accumulated at the point in question. This explains why sapid impressions are so intense upon that part of the dorsal surface which is at a distance from the point

of the tongue equal to two-thirds of its length, the elementary papillæ there forming groups so remarkably voluminous. One of the calyciform papillæ found in the region of the tongue, as examined by Professor Sappey, was magnified twenty times in its linear dimensions. It appeared from this, that not only that which appears to the naked eye as a large central papilla is composed of innumerable minute elementary papillæ, but also that the surrounding circular ridge is similarly constituted.

864. According to the same authority, the sensibility of the tongue upon the point and borders is also explained by the groups of papillæ of the second order, called fungiform, which are accumulated there. The sensibility of the middle part of the upper surface between the region of calyciform papillæ and the extremity, and the complete insensibility of that part which is situated behind the calyciform papillæ, is explained by the fact that in the former part papillæ of the third order only prevail mingled with but few groups of the second and inferior orders, and that in the latter region the only papillæ found are those of the lowest order. Like considerations explain the absence of gustatory sensibility in the inferior part of the tongue.

The relation thus established, observes Professor Sappey, between the number of elementary papillæ found at any given point of the lingual surface and the degree of special sensibility with which that part is endowed, is so true that we find it not less manifest upon another part of the mouth endowed, like the tongue, with the property of being affected by sapid substances. It has been demonstrated by experiment that the anterior part of the vault of the palate possesses gustatory sensibility in a remarkable degree ; and we find, in accordance with this principle, upon this point, and upon this point only, a voluminous calyciform papilla, situate upon the median line behind the middle incisives, and round it a crowd of tubercles in ridges, bristling with elementary papillæ.

865. **Nerves of the Tongue.**—The mucous membrane of the tongue which, as has been observed, is the seat of gustative sensibility, is supplied with nerves from two principal sources : first, from the trigeminal or trifacial nerves, being those of the fifth pair, the origin of which is shown at 244[27]; and, secondly, from the glosso-pharyngeal, or ninth pair, the origin of which is shown at 244[27]. According to Professor Sappey, filaments are also sent to this membrane by the pneumo-gastric, or tenth pair, the origin of which is shown at 244[32].

The trigeminal sends a voluminous branch called the *lingual nerve* into the lower jaw, the course of which is shown at 270[3] and 271[14]. This branch entering the tongue, as shown at 416[k], ramifies through the

organ, its filaments terminating in the mucous membrane of the superior surface. It supplies all that part of the tongue which extends from the point over three-fifths of its length. The posterior two-fifths are supplied with nervous filaments by the principal branch of the glosso-pharyngeal, the course of which on entering the tongue is shown at 416 [l].

The pneumo-gastric nerve sends to the tongue some small ramifications, which proceed from the superior laryngeal branch. The ramifications of this nerve which supply the larynx are shown at 271 [6] and 271 [7], but do not appear in 416. They pass into the tongue, losing themselves in that part of the mucous membrane which is situated immediately before the epiglottis, which is not endowed with sapid sensibility. This nerve,

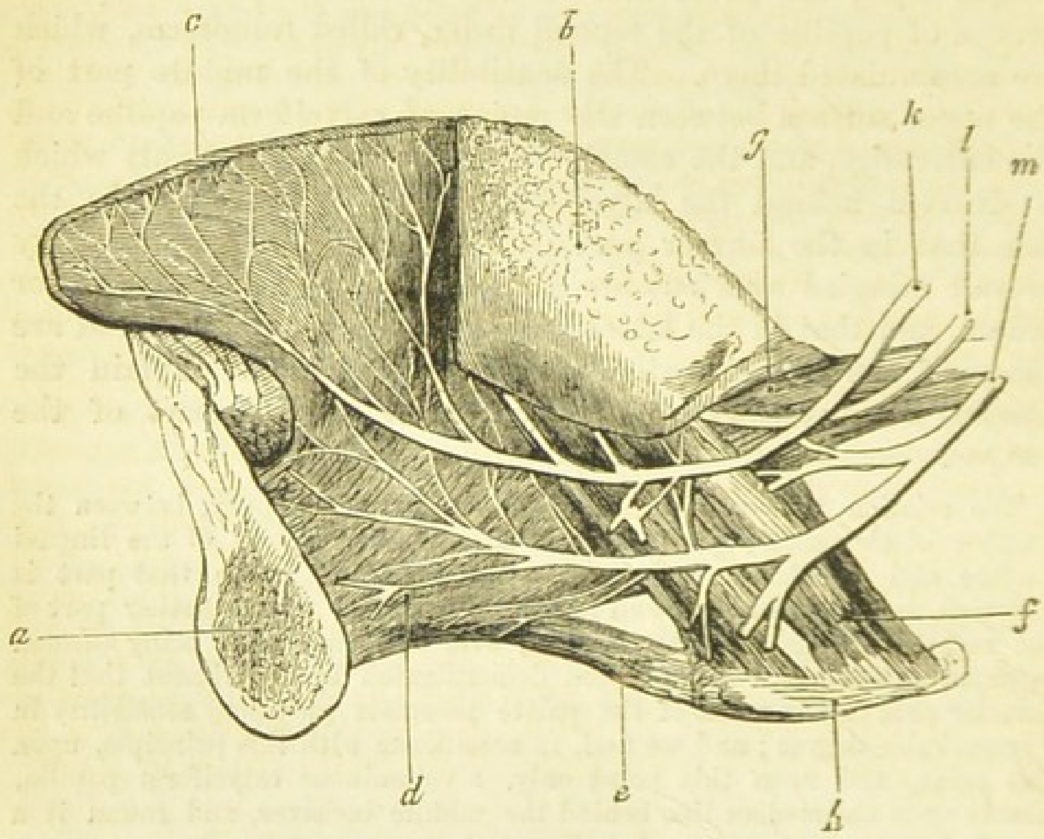


Fig. 416.
NERVES AND MUSCLES OF THE TONGUE (Béclard).

a. Section of the bone of the lower jaw.
b. Dorsal or superior surface of the tongue.
c. Vertical section of the tongue.
d. Genio-glossal muscle.
e. Genio-hyo-glossal muscle.
f. Hyo-glossal muscle.
g. Stylo-glossal muscle.
h. Hyoid bone.
k. Lingual nerve.
l. Glosso-pharyngeal nerve.
m. Hypoglossal nerve.

therefore, cannot properly be considered as a gustatory nerve. The motor nerve of the tongue is the hypoglossal (416 [m]), which spreads its ramifications exclusively through the lingual muscles.

The lingual (416 [k]) and glosso-pharyngeal (416 [l]) are therefore, according to some authorities, the nerves of gustatory sensibility. The former, after traversing the muscles, terminates in the papillæ situated in front of the lingual Λ (858). The latter, after having spread itself under the

mucous membrane, terminates in the calyciform papillæ and those of the other classes with which these are surrounded. Both these nerves impart, also, tactile sensibility to the parts over which they are distributed. Whether each individual fibre be endowed at once with the tactile and the gustatory sensibility, or whether the nerve, having these sensibilities, consists of two distinct fibres in juxtaposition, one gustatory and the other tactile, physiologists have not decided. The latter hypothesis, however, appears to have been more generally accepted. To establish it by absolute demonstration, it would be necessary to isolate the two sensibilities upon the same trunk by paralysing, for example, the gustatory and preserving the tactile; but the two fibres, if such exist, endowed with these distinct properties, are so intimately connected that their separation has not hitherto been found possible. According to Professor Bérard, however, nature has in some cases performed this experiment. That anatomist records six cases of the paralysis of the tactile sensibility, the gustatory remaining unimpaired. Upon the hypothesis of the double sensibility in a single fibre, it would be impossible to explain these phenomena, whereas their explanation is easy and obvious upon the other supposition.*

A controversy has prevailed among physiologists as to whether the lingual branch of the fifth pair or the glosso-pharyngeal nerve be the nerve of taste. Wagner, Panizza, Valentin, and Bruns place the principal seat of gustatory sensibility in the glosso-pharyngeal nerve, while Müller, Kornfeld, and Gwilt give it to the lingual branch of the fifth. The latter physiologists consider Valentin's experiments proving the glosso-pharyngeal to be the principal gustatory nerve as inconclusive, inasmuch as the animal in which it was divided recovered its taste within a fortnight, a period so short as to render it probable that the sense was never lost. They regard Dr. Alcock's experiments also as inconclusive. That physiologist inferred that the sense of taste was seated not only in the glosso-pharyngeal and lingual branch of the fifth, but also in the palatine branches of the fifth. It appears certain, according to Müller, as well from his own experiments as from those of Magendie, Gwilt, Kornfeld, Parry, Bishop, and Romberg, that the larger branch of the fifth is the principal gustatory nerve, although the absence of gustatory sensibility from the glosso-pharyngeal at the posterior part of the tongue and in the fossæ is not proved.

866. **Terminal Form of Lingual Nerves.**—Whether the nerves of gustation terminate in what anatomists call a free extremity in the various papillæ, or are looped in the manner formerly described (30), has not been determined. Each of these two hypotheses has had its partisans. Burdach, who favours the loop form, says, that he has observed it in the nerves upon the point of the tongue of a frog; and Valentin appears to have arrived at the same result by the application of caustic potash. Professor Sappey has made numerous experiments upon the human tongue to determine this point, but has hitherto failed to discover any appearance which gives decided

* Bérard, Traité de Physiologie. Sappey, Traité d'Anatomie, vol. ii. p. 764.

countenance to the one or the other hypothesis. He has only found that the nerve occupies the smallest imaginable space in the interior of the papillæ, nearly the entire volume of which consists of mucous membrane, cellular tissue, arteries, veins, and lymphatics.*

867. **Vascular Apparatus of Mucous Membrane.**—The lingual membrane is richly supplied with arteries, veins, and lymphatics. The arteries consist of innumerable ramifications proceeding from the lingual artery which supplies the subjacent muscles. The veins are, however, independent of those of the muscles, and consist of three groups—one superior or medial, and two inferior or lateral.

868. From all that has been stated, it will be understood that much difference prevails among physiologists, and that much remains still to be discovered respecting the exact seat of gustatory sensibility. Thus Messrs. Panizza and Valentin deny this sensibility to the point of the tongue, and localise it upon its upper surface and the superior part of the pharynx. They consequently regard the glosso-pharyngeal nerve as the special nerve of taste, and impute to the lingual nerve nothing more than the tactile sensibility, which is admitted on all hands to be eminently delicate at or near the point of the tongue, where the filaments of the lingual nerve are most numerously distributed.

The gustatory sensibility of the point of the tongue is regarded by most physiologists as very doubtful, and it is contended that the great delicacy of the tactile sensibility has led many erroneously to impute the other special sense to it. It is certain that many sapid substances affect this part of the tongue, but in a manner rather tactile than gustatory.

869. M. Panizza having divided the glosso-pharyngeal nerve of dogs, found that complete loss of taste ensued. A dog thus treated ate indifferently meat in its natural state and meat impregnated with colocynth, and also swallowed drinks with the greatest facility in which the same bitter principle was dissolved. Now it is known that the healthy animal entertains an insurmountable disgust to colocynth.

870. Admitting that the glosso-pharyngeal nerve is exclusively endowed with gustatory sensibility, it must also be admitted that it possesses the tactile sensibility, whether both

* Sappey, Traité d'Anatomie, p. 765.

these properties be ascribed to the same fibres, or, according to the other hypothesis, the nervous cords be assumed to consist of different fibres endowed with the two sensitive principles. If this double function therefore be ascribed to the glosso-pharyngeal nerve some countenance is given to this supposition, which would ascribe a like double function to the lingual nerve.

871. **The Sense of Taste of Inferior Animals** is much less developed than with man. It is not the sense of taste, but generally that of smell, which guides them in the choice of their food, since this choice always precedes its prehension. The uncertainty which exists as to the precise seat of the sense of taste in man is still greater in the case of inferior animals. It is probable that the superior part of the digestive cavities, such as the pharynx, which, in man, shares with the tongue the property of transmitting gustatory impressions, presides alone over the perceptions of taste in most of the animals which want the tongue, and even in those in which that organ, being converted into an instrument of prehension, is horny or supplied with a sort of dental appendages.

872. **The Tongue of Mammifers** in general resembles that of man. The tongue of the dog is covered with soft and numerous papillæ. That of the larger ruminants, of the cat, and animals of the same class, is supplied with papillæ inclined backwards and inclosed in a horny sheath more or less thick. When a ruminant browses, these papillæ fix upon the tongue the grass which the animal seizes. When a carnivorous animal licks the prey which it has torn, the rugged surface of the tongue tends to make the blood upon which it feeds issue forth. Other mammifers, such as ant-eaters, echidnæ, cetaceæ, and so on, have a tongue nearly deprived of papillæ, and therefore destitute of gustatory sensibility.

873. **Birds** have a very obtuse sense of taste. They swallow their food almost without mastication. The tongue is generally hard and semi-cartilaginous, especially near the point. Granivorous birds are particularly remarkable in this respect; but birds of prey, which live on flesh, are supplied with a more fleshy tongue.

874. **Reptiles** have in some cases a thick fleshy tongue, but

it is more generally thin, protractile, often bifid, and constitutes rather an organ of prehension than of taste.

875. **Fishes** have a tongue scarcely more than rudimentary. With many of them it is almost immovable, and furnished, like most of the other parts of the buccal cavity, with horny or bony appendages which enable the animal to retain its prey. If fishes be endowed with taste at all, its seat must be limited to the superior part of the digestive canal.

876. **Invertebrata** are nearly in the same case, having nothing which resembles a tongue. If they possess the gustatory sense, which insects probably do, its seat must be the soft parts of the mouth, the suckers, or the proboscis.

CHAPTER XV.

VISION.

877. Of all the organs of sense, the eye is that to which we are most deeply indebted. It opens to us the widest and most varied range of observation. The pleasures and advantages it affords, directly and indirectly, have neither cessation nor bounds. It guides our steps through the world we inhabit, and invests us with a space-penetrating power to which there is no practical limit.

Although vision, strictly speaking, is only cognisant of light and colour, yet, from the habitual comparison of the connection of these with the forms of bodies, as ascertained by touch, we acquire the greatest facility, promptitude, and precision in recognising, by sight alone, the forms, magnitudes, motions, distances, and relative positions, not only of all the objects which immediately surround us, but also of innumerable others which are altogether inaccessible.

This sphere of observation, however, vast as it is, forms but a small part of the power conferred by the eye. We have, besides, the inestimable advantages attending the ability it bestows upon us to acquire knowledge through books, to converse with and be instructed by the learned, the wise, and the virtuous of all ages ; and although those who have the misfortune to be deprived of vision can, to some extent, replace it by the ear, aided by the eye of another, yet this and all like expedients supply results infinitely small and insignificant compared with those obtained by the organ of vision itself.

878. Apart from its uses, the eye itself is a most interesting and instructive object of study. It presents, beyond comparison, the most beautiful example of design to be found in the animal economy. Nowhere can we find so remarkable an adaptation of means to an end—means consisting of the most perfect combination of scientific principles, and an end manifesting a will directed by boundless beneficence.

879. **The Visual Apparatus** in man and the higher animals consists of three chief parts : 1st, the organ of sense itself ;

2nd, the parts by which the impressions upon it are transmitted to the brain ; 3rd, the parts by which it is moved and protected, and its efficiency maintained.

880. **Structure of the Eye.**—In the human race the organ of vision consists of two hollow spheres, each about an inch in diameter, filled with certain transparent liquids, and deposited in cavities of suitable magnitude and form in the upper part of the front of the skull, on each side of the nose.

These cavities are lined with soft matter, serving as a cushion for the protection of the eyeballs, which can move freely in them, the surfaces being lubricated by fluids secreted in surrounding glands. The organs are further protected from external injury by the projecting bones of the forehead above, forming the brows, the bones of the temples on the outside, those of the cheeks below, and those of the nose on the inside.

The eyeballs are constructed so as to form upon the posterior part of the inside surface of each of them an optical picture of every external object placed before them. They are nearly spherical, and the transparent fluids called humours, which fill the internal cavities, are inclosed in a triple membranous envelope.

The external coat, called the *sclerotic*, upon which the maintenance of the form of the eye chiefly depends, is an opaque, tough structure, composed of bundles of strong white fibres, interlacing each other in all directions. It covers about four-fifths of the eyeball, leaving two circular openings,—a large one in front, covered by a transparent convex piece of nearly uniform thickness, called the *cornea*, and a smaller one behind, the embouchure of the *optic nerve*, which, proceeding backwards and upwards, and passing through foramina in the bones of the skull, terminates in the brain. It is by this nerve that the impressions of external objects are transmitted to the seat of perception.

881. **The Cornea,** closely united at its edge with the corresponding edge of the circular opening in the sclerotic, is slightly elliptical, its horizontal being rather longer than its vertical diameter. Its external surface

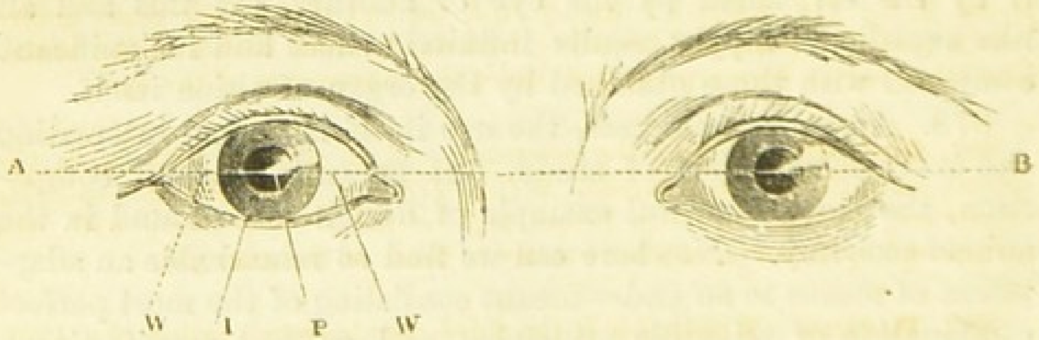


Fig. 417.

is more convex than that of the sclerotic, so that it forms a segment of a sphere smaller than that of the general surface of the eyeball. It there-

fore projects outwards in front of the eye, rendering that axis of the eye which passes through its centre a little longer than the diameters, at right angles to it. Being of nearly uniform thickness, the concavity of its inner surface corresponds with the convexity of its outer, and gives the whole the form of a watch-glass, or a concavo-convex lens, whose surfaces have equal radii.

In looking at an open eye, that part of the sclerotic which is uncovered is what is popularly called the *white of the eye*, and the cornea covers the coloured part.

A front view of the eyes and surrounding parts is shown in fig. 417 ; a section of them, made by a horizontal plane through the line A B passing through the centre of the front of the eyeballs, being shown in fig. 418.

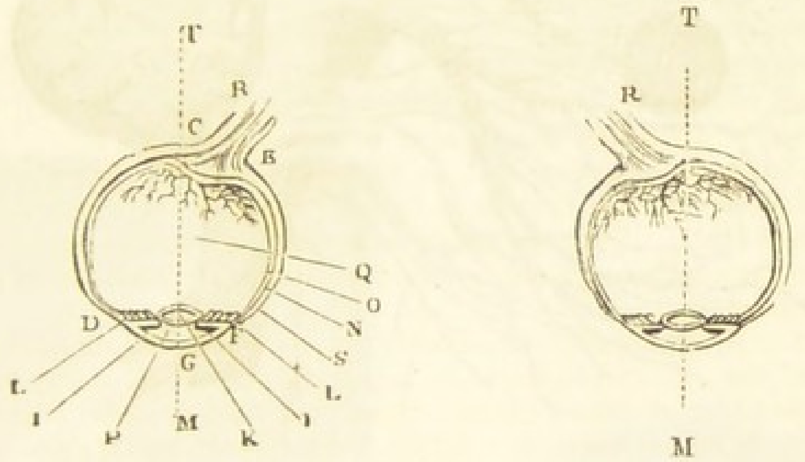


Fig. 418.

The sclerotic is shown at C D F E, and the cornea at D G F.

A line, M T, drawn through the centre of the cornea and the centre of the eyeball, is called the *optic axis*, and the embouchure, C E, of the optic nerve lies at the distance of about the tenth of an inch from this axis, between it and the nose. The optic nerves, R, therefore, issuing from the two eyeballs at the corners, beside and behind the nose, proceed in a converging direction to the brain, as shown in fig. 418.

The connection of the seat of vision with the brain by the optic nerve is shown in fig. 419, where S is the eyeball, the end of the optic nerve entering its posterior part, and receding backwards from thence to the brain. The other nerves here represented direct the movements of the eye.

882. **Choroid.**—Within the sclerotic, and in contact with it, is the second coat, called the *choroid*, N (fig. 418), a dark-coloured vascular membrane, having openings before and behind corresponding with the cornea and optic nerve, similar exactly to those of the sclerotic.

883. **Retina.**—Within this is the third membranous coating (fig. 420), called the *retina*, which is, in fact, the continuation of the fibres of the optic nerve spreading over the chief part of the internal surface of the eyeball. It is a delicate, pulpy, and perfectly transparent membrane, spread over all the posterior and lateral parts, terminating near the margin of the frontal opening covered by the cornea already described.

884. **Crystalline.**—As the frontal opening of the sclerotica is closed by the cornea, that of the choroid which corresponds with it in position is

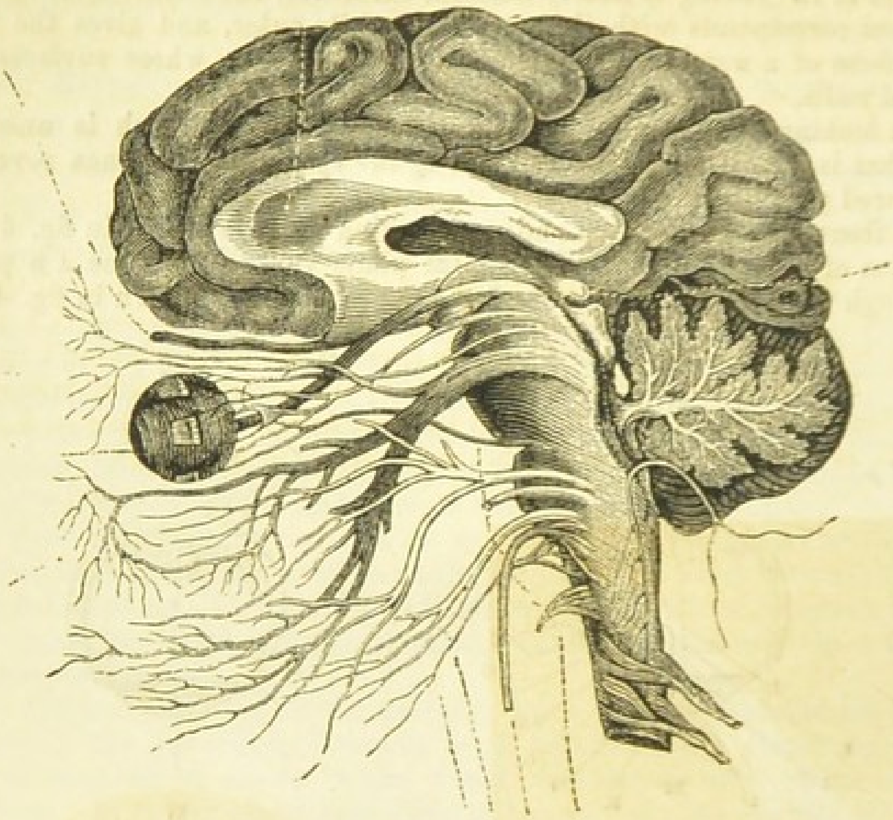


Fig. 419.

closed by a transparent double convex piece, called the *crystalline lens*, the axis of which coincides exactly with the optic axis, and is consequently concentric with the cornea. It is fixed by means of a series of converging folds of that membrane, called the *ciliary processes*. The annular surface formed by these processes, and the crystalline lens which they surround and support, form the posterior side of a compartment in the front of the eyeball, separated completely from the larger compartment behind the crystalline lens. This arrangement will be more clearly comprehended by the enlarged section of the front of the eye given in fig. 420, where 2 is the sclerotica, 3 the cornea, *b* the crystalline lens, and 6 the ciliary processes.

885. **The Iris** is a thin flat annular diaphragm, the section of which is shown at 7, dividing the space between the crystalline lens and the cornea unequally into two parts, called the *anterior chamber*, *a*, and the *posterior chamber*, *á*.

The external or anterior surface of the iris is coloured blue, black, or hazel, differently in different eyes, and is the part which, seen through the transparent cornea, gives the characteristic colour to the eye.

886. **The Pupil** is a circular opening surrounded by the iris, through which the light received through the cornea is transmitted to the crystalline lens. By this means there is admitted to the crystalline a pencil of rays whose external limits are determined by the edges of the iris. The posterior

surface of the iris is covered by a black pigment, contained in a thin transparent membrane, called the *uvea*.

In fig. 421 a view of the ciliary processes (1) which surround and support the crystalline lens is given. That lens, however, being supposed to be removed, the converging folds of which they consist are shown, and the iris (2) is seen by its dark posterior surface through the space filled by the crystalline, with the pupil (3) in its centre. When seen from the front, the pupil appears as a black circular spot P (fig. 417), surrounded by the coloured ring of the iris, because every part of the interior of the eye which could be visible through it is coloured black.

887. **The Aqueous Humour** fills the compartment of the eye between the cornea and crystalline, and, as its name implies, is a watery fluid, holding in solution very minute quantities of albumen and common salt. It is separated from the cornea by an extremely thin transparent membrane, shown at 420, [11], called the *membrane of the aqueous humour*, which, however, is represented much too thick in the figure.

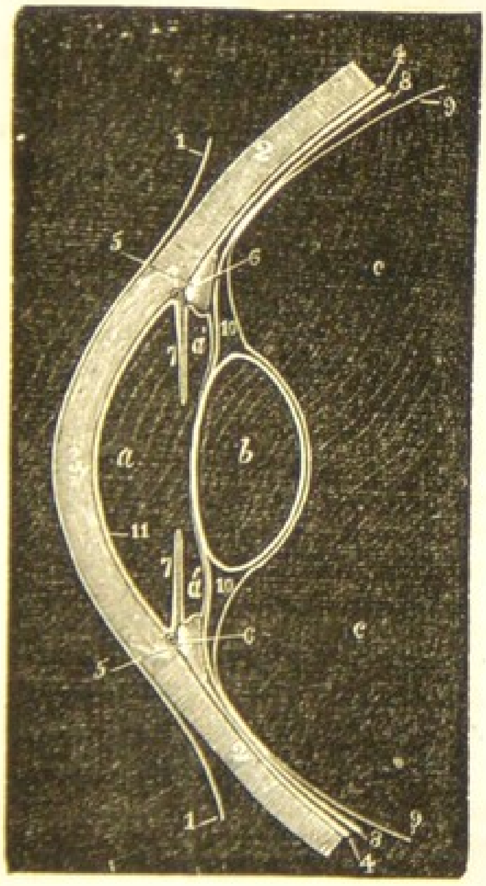


Fig. 420.

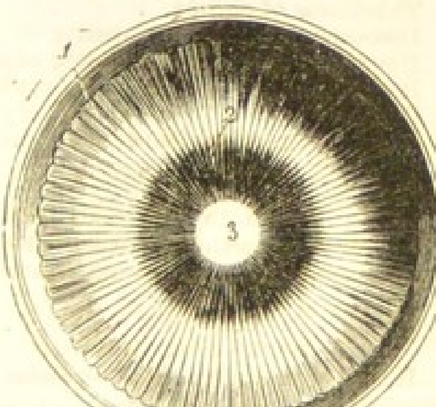


Fig. 421.

The Crystalline Lens (420, [b]) is enclosed in a transparent capsule, and consists of transparent matter, which increases in density and in its refractive power, proceeding from its external surface inwards, and from its edges to its centre.

888. **The Vitreous Humour** fills the posterior compartment of the eye (420, [cc]) behind the crystalline, and constitutes by far the largest part

of the internal cavity. This is not in immediate contact with the retina, being enclosed in a fine transparent membrane called the *hyaloid* (420, [9]).

889. **The Eyelids** are not in immediate contact with the sclerotic or the cornea. A fine mucous membrane, called the *conjunctiva*, which lines their inner surface, is reflected over the fore part of the sclerotic and the anterior surface of the cornea. A part of this membrane is shown in section at 420, [1].

890. **The Eyebrows and other Accessories** are provided for the protection and preservation of the organ of vision. The eyebrows across the edge of the projecting part of the forehead catch the sweat descending from above, and prevent it from falling on the eyes, and aid in shading the eyes from too intense light from above. The eyelids are movable screens, made so as to cover the eye or leave it exposed, as occasion may require. Glands are provided, by which all the parts which move in contact one with another are kept constantly lubricated.

891. **Numerical Data of the Structure.**—The following are the principal numerical data connected with this organ :—

	100ths of Inch.
Radius of sclerotic coating	39 to 43
Radius of cornea	28 ,, 32
External diameter of iris	43 ,, 47
Diameter of pupil	12 ,, 28
Thickness of cornea	4
Distance of pupil from centre of cornea	8
Distance of pupil from centre of crystalline	4
Radius of anterior surface of crystalline	28 ,, 39
Radius of posterior surface of crystalline	20 ,, 24
Diameter of crystalline	39
Thickness of do.	20
Length of optic axis	87 ,, 95
Index of refraction from air into aqueous humour	1·3366
Index of refraction from air into vitreous humour	1·3394
Index of refraction from air into crystalline humour :—	
At the surface	1·3767
At the centre	1·3990
At the mean	1·3839
Index of refraction from aqueous humour to crystalline humour :—	
At the surface	1·0466
At the mean	1·0353
Index of refraction from vitreous humour to crystalline humour :—	
At the surface	1·0445
At the mean	1·0332

According to Sir D. Brewster, who has supplied the preceding indices of refraction, the focal length of the crystalline is 1·73 inches.

892. **The Motor Apparatus,** by means of which the optic axis can be directed at will within definite limits to surrounding objects, consists of muscles inserted at various points of the sclerotica, and having their origin in the bones of the socket. These muscles are acted upon by a corresponding system of nerves.

The motions thus imparted to the eyeball are facilitated by a

lubricating fluid secreted by a gland, called the lachrymal gland, placed over the eyeball. This fluid is continually spread upon the surface of the sclerotic, by the motion of the eyelids in winking.

In fig. 422 the motor muscles and the lachrymal gland of the right eye are shown by the removal of the lateral bony parts of the external side of the socket.

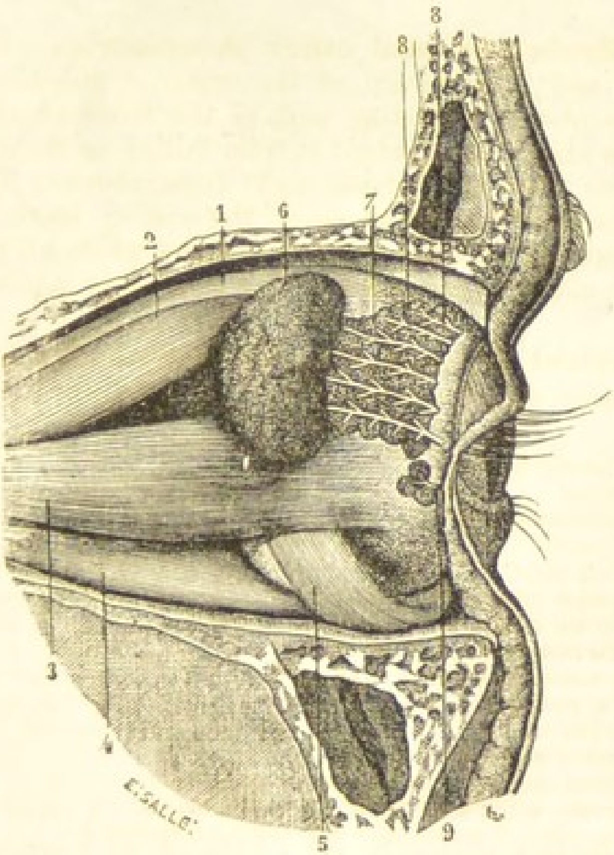


Fig. 422.

MOTOR MUSCLES AND LACHRYMAL GLAND OF RIGHT EYE (Sappey).

1. Muscle which raises the eyelid. The tendinous expansion of this muscle has been cut away to display the palpebral portion of the lachrymal gland covered by it.
2. M. which directs the optic axis upwards.
3. M. which directs the axis outwards.
4. M. which directs the axis downwards.
5. M. of unascertained use.
6. Orbital part of lachrymal gland.
7. Palpebral part traversed by four ducts of orbital part and sending into these small ducts or canalicules.
8, 8. Accessory ducts proceeding exclusively from the superior border of the palpebral part.
9. Another accessory duct with three lobules.

In fig. 423, the lachrymal gland, the eyelid, and accessories are removed in order to display the parts they conceal.

893. **The Limits of the Play of the Eyeball** are as follows: —The optic axis can turn in the horizontal plane through an angle of 60° towards the nose, and 90° outwards, giving an

entire horizontal play of 150°. In the vertical direction it is

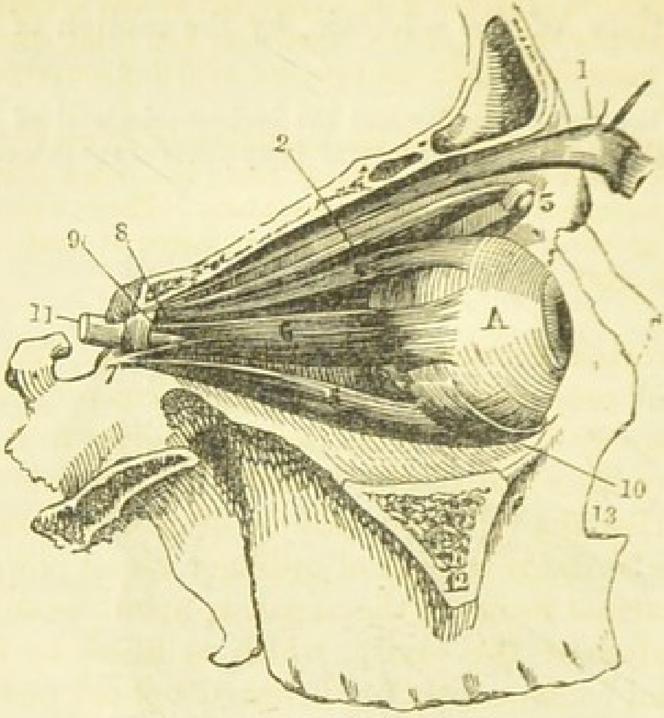


Fig. 423.

The insertion of the three muscles marked 2, 3, 4, in fig. 422, but here marked 2, 5, 6, upon the sclerotic are apparent. A fourth muscle inserted on the inside of the eyeball, by which the optic axis is directed inwards, is concealed. These four are called the straight or recti muscles.

The muscles 423^{7}, and 423^{10}, are called the superior and inferior oblique. Physiologists are not agreed as to their use, but 423^{2}, is supposed to move the axis upwards and inwards, and 423^{10}, downwards and inwards.

423^{1}, is the muscle which elevates the eyebrow.

423^{3}, the pulley of the M. 423^{2}.

423^{11}, optic nerve. 423^{12}, section of the jawbone. 423^{13}, upper jaw.

capable of turning through an angle of 50° upwards and 70° downwards, giving a total vertical play of 120°.

894. **Ocular Image.**—The structure of the eye being thus understood, it will be easy to explain the effect produced within it by luminous or illuminated objects placed before it.

Let us suppose a pencil of light proceeding from any luminous object, such as the sun, incident upon that part of the eyeball which is left uncovered by the open eyelids.

That part of the pencil which falls upon the white of the eye, W (fig. 417), is irregularly reflected, and renders visible that part of the eyeball. Those rays of the pencil which fall upon the cornea pass through it. The exterior rays fall upon the iris, by which they are irregularly reflected, and render it visible. The internal rays pass through the pupil, and are incident upon the crystalline, which, being transparent, is also penetrated by them; they then pass through the vitreous humour, and finally reach the posterior surface of the inner part of the eye, where they penetrate the transparent retina, and are received by the black surface of the choroid, upon which they produce an illuminated spot.

The aqueous humour being more dense than the external air, and the surface of the cornea, which includes it, being convex, rays passing from the air into it will be rendered more convergent or less divergent. In like manner, the anterior surface of the crystalline lens being convex, and that humour being more dense than the aqueous, a further convergent effect will be produced.

Again, the posterior surface of the crystalline being convex towards the vitreous humour, and this latter humour being less dense than the crystalline, another convergent effect will take place. These rays passing successively through these three humours, are rendered at each surface more and more convergent.

895. **Inverted Picture.**—The eye, therefore, has the optical character and properties of a compound convergent lens, and will consequently form, at some point posterior to it, an optical image of any illuminated object which is presented before it. It is found that the refractive powers of the humours, and the form of their surfaces in eyes of ordinary visual power, are such that the principal focus of the organ is upon the retina at the posterior surface of the cavity, which is filled by the vitreous humour ; and consequently an inverted optical picture of any distant object placed before the eye will be projected upon this part of the retina.

That this phenomenon is actually produced in the interior of the eye may be rendered experimentally manifest by taking the eyeball of an ox recently killed, and dissecting the posterior part, so as to lay bare the choroid. If the eye thus prepared be fixed in an aperture in a screen, and a candle be placed before it at a distance of eighteen or twenty inches, an inverted image of the candle will be seen through the choroid, as if it were produced upon ground glass or oiled paper.

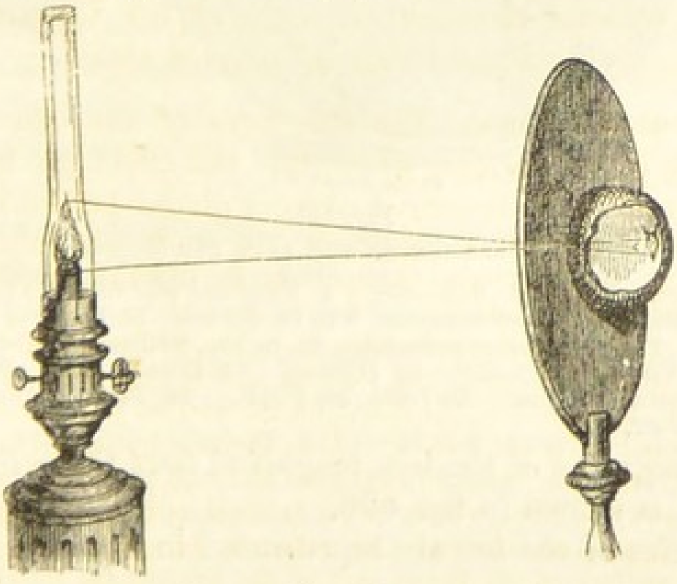


Fig. 424.

The phenomenon can be still more manifestly shown by making an open-

ing carefully at the upper part of the eyeball, so that the posterior part of the retina may be visible through the vitreous humour. In this case the image of any bright object, such as the window, to which the optic axis may be directed, will be seen depicted on the retina. The experiment may be more easily performed, according to the method suggested by Magendie, by means of the eye of any albino animal, such as a white rabbit, in which the coats, from the absence of pigment, are transparent. Such an eye being dissected clean, and presented with its axis towards a window, a very distinct image of the window completely inverted will be seen depicted on the posterior semi-transparent wall of the organ.

896. Although the figures given above may suffice to show the relative forms and position of the parts composing the interior of the eyes, anatomical sections and views, taken under conditions of greater precision, are necessary to convey exact notions of the curious and complicated structure of the organ.

In fig. 425 a vertical section of the left eye made in the median plane is given on a scale exactly twice the natural linear magnitude of the organ. The parts indicated are as follows :—

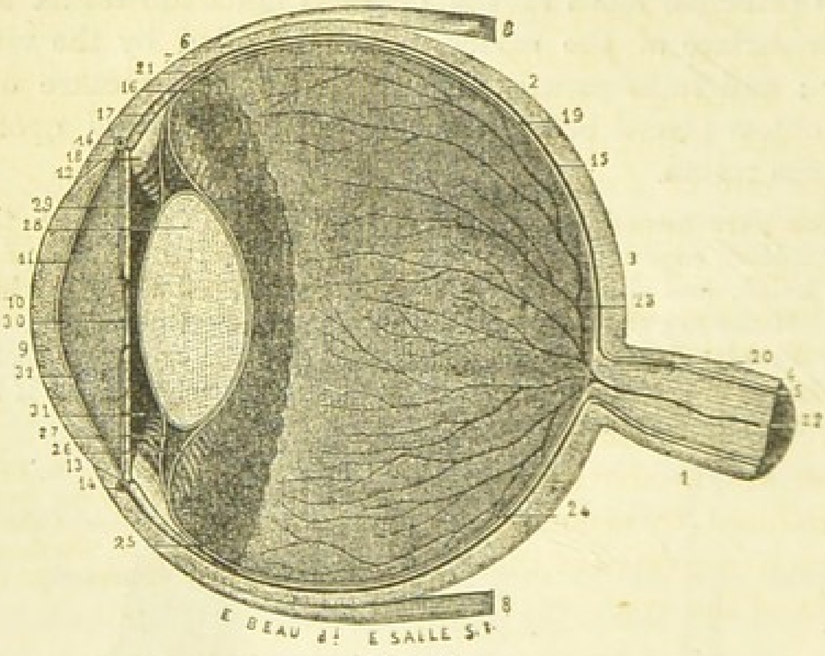


Fig. 425.

VERTICAL SECTION OF THE LEFT EYE (Sappey).

1. Optic nerve. 2, 3, 6, 7. Sclerotic. 4. External coat of optic nerve. 5. Internal coat of ditto. 8. Motor muscles. 9 to 13. Cornea. 14. Canal of Fontana. 15, 16. Choroid. 17, 18. Ciliary processes. 19 to 21. Retina. 22. Central artery of retina. 23. Vitreous humours. 24. Hyaloid. 25. Zone of Zinn. 26, 27. Canal of Petit. 28. Crystalline lens. 29. Iris. 30. Pupil. 31. Posterior chamber. 32. Anterior chamber.

897. A segment of the iris, magnified four times in its linear dimensions, is shown in fig. 426.

The arteries of the iris are represented in fig. 427.

898. **Eye Achromatic and Aplanatic.**—That the eye is sensibly achromatic is proved by the fact that the objects we

behold are not edged with coloured fringes, as is the case with all lenses which are not achromatic. But if, by any means, an object be seen out of focus, that is, so that its image shall fall either before or behind the retina, the achromatism ceases, and coloured fringes become apparent. The cases in which objects are thus seen out of focus will be presently indicated. It is also evident that the eye is aplanatic, or exempt from any sensible spherical aberration, since if it were not, the images on the retina, and consequently the perception of the objects producing them, would be more or less indistinct, which they are not. But if they are seen out of focus, as will presently appear, they become so. It appears, then, that the immediate cause of vision, and the immediate object of perception in the sensorium when we see, is the image thus produced by means of the refractive powers of the humours of the eye.

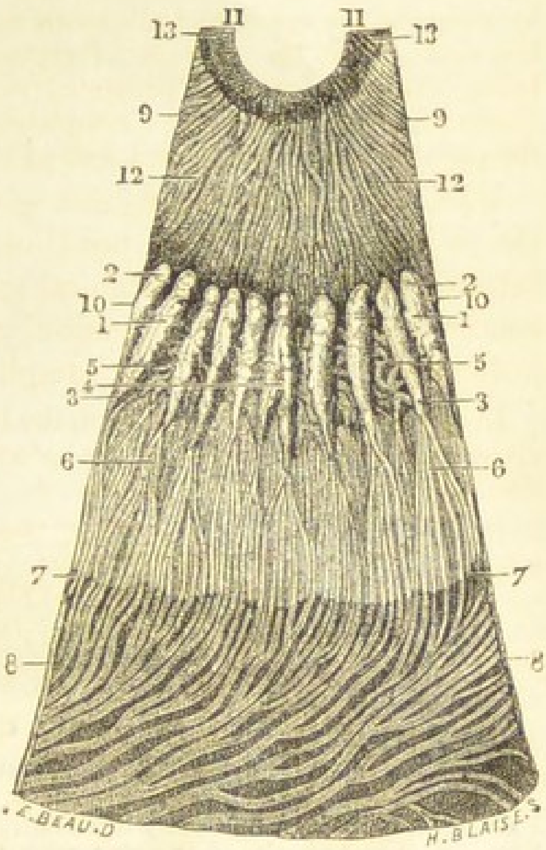


Fig. 426.

SEGMENT OF IRIS MAGNIFIED (Sappey).

1 to 5. Ciliary processes. 4. Bifurcated process. 6. Veins ramifying from summits. 7. Festooned border of choroid. 8. Veins of choroid. 10, 11. Borders of iris. 12. Radiating fibres of iris. 13. Circular fibres.

899. **Other Analogies to an Optical Instrument.**—Not only does the iris play the part of the diaphragm provided in telescopes and microscopes to intercept the lateral rays and all stray light (being, however, more perfect than any ordinary diaphragm, inasmuch as it is capable of enlarging and contracting the opening according as circumstances require), but its posterior surface is coated with a black pigment, so that it cannot reflect the light which it intercepts. The posterior surface of the ciliary processes is covered with the same black pigment which coats the choroid,—a provision which has the same general effect in absorbing any rays of light which may be

reflected within the eye, and preventing their being thrown again upon the retina, so as to confuse the image formed upon

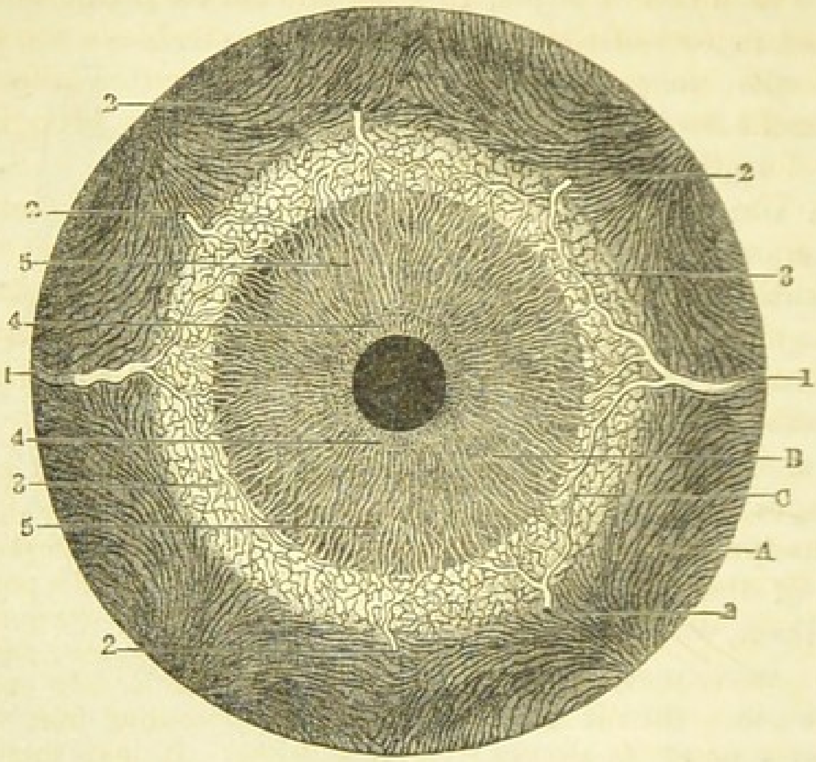


Fig. 427.

ARTERIES OF IRIS (Arnold).

A. Choroid. B. Iris. C. Ciliary ligament. 1. Posterior ciliary artery. 2. Anterior ditto. 3. Anastomosis of anterior with posterior. 4. Inner border of iris. 5. Artery extending from outer to inner border.

it. The black colour given to the inner surface of telescopes and microscopes is applied for a like purpose.

900. **The Conditions of Perfect Vision** are :—

1. The image on the retina must be perfectly distinct.
2. It must have sufficient magnitude.
3. It must be sufficiently illuminated.
4. It must continue on the retina for a sufficient length of time.

901. **Distinctness of Image.**—The image formed on the retina will be distinct or not, according as the pencils of rays are brought to an exact focus on the retina or not. If they be not brought to an exact focus on the retina, their focus will be a point beyond the retina or within it. In either case the rays proceeding from any point of the object, instead of forming a corresponding point on the retina, will form a spot of greater or less magnitude, according to the distance of the focus of the

pencil from the retina, and the assemblage of such luminous spots will form a confused picture of the object. This deviation of the foci of the pencils from the retina is caused by the refracting powers of the eye being either too feeble or too strong. If too feeble, the rays are intercepted by the retina before they are brought to a focus; if too strong, they are brought to a focus before they arrive at the retina.

902. The objects of vision may be distributed into two classes, in relation to the refracting powers of the eye: 1st, those which are at so great a distance from the eye, that the pencils proceeding from them may be regarded as consisting of parallel rays: 2ndly, those which are so near that their rays have sensible divergence.

It has been stated that the diameter of the pupil varies from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in magnitude, the variation depending upon a power of dilatation and contraction with which the iris is endued. Taking the diameter of the pupil at its greatest magnitude of a quarter of an inch, pencils proceeding from an object placed at the distance of three feet from the eye would have an extreme divergence amounting to about a third of a degree; and if the pupil be in its most contracted state when its diameter is only one-eighth of an inch, then the divergence of the pencils proceeding from such an object would amount to about a sixth of a degree. It may therefore be concluded that pencils proceeding from all objects more distant from the eye than two or three feet may be regarded as consisting of parallel rays.

The pencils of rays, therefore, proceeding from all such objects, will be made to converge to the principal focus of the eye.

903. **Optical Centre.**—Sir David Brewster concludes that the optical centre of the eye, that is to say, the point at which the axes of secondary pencils intersect the optic axis, is situate in the geometric centre of the eyeball, and consequently must be a little within the crystalline. If, therefore, round this centre we imagine a spherical surface described, whose radius is equal to the focal distance of the combination of the humours of the eye, the images of all objects more distant from the eye than two or three feet will be found on such a surface. Now, since the retina is spread over the surface of the choroid, and since the form of the eye is very nearly spherical, and its diameter but an inch, it follows that the retina is a concave spherical surface, whose centre coincides with the optical centre of the eye, and is at a distance from that centre of about half an inch. If the distance of the retina from this centre be exactly equal to the focal distance of the humours, then the foci of all pencils of parallel rays entering the eye will be formed upon it, and

consequently it will receive distinct images of all objects whose distance from the eye exceeds two or three feet. But if the focal distance of the humours be less or greater, then, as already stated, the image on the retina will be indistinct.

904. **Optical Remedies for Defects in the Refracting Powers of the Eye** are supplied by the properties of convergent and divergent lenses. If the eye possess too little convergent power, a convergent lens is placed before it, which, receiving the parallel pencils, renders them convergent when they enter the pupil, and this enables the eye to bring them to a focus on the retina, provided the power of the lens be equal to the deficient convergence of the eye. If, on the other hand, the convergent power of the eye be too great, so that the parallel rays are brought to a focus before arriving at the retina, a divergent lens is placed before the eye, by means of which parallel pencils are rendered divergent before they enter the pupil; and the power of the lens is so adapted to the convergent power of the eye, that the rays shall be brought to a focus on the retina.

The two opposite defects of vision here indicated are generally called, the one *weak-sightedness* or *far-sightedness*, and the other *near-sightedness*.

905. **Adaptation to Different Distances.**—If it be admitted that the formation of a distinct picture at the posterior part of the eye be essential to distinct vision, and that the focus of the eye be regulated by the same principles as that of a convergent lens, it will necessarily follow that, supposing the eye to be so constituted as to have its principal focus on the retina, the foci of all pencils of divergent rays must necessarily be behind the retina. Now, since all objects at less distances from the eye than two feet transmit pencils sensibly divergent, the foci of all such pencils being behind the retina, the picture on the retina, and, consequently, the vision of the object, would be necessarily indistinct; and the less the distance of the object from the eye, the greater would be the distance of the foci of the pencils behind the retina, and the more indistinct would be the vision.

Nevertheless, it is found, in fact, that eyes which are capable of distinct vision at distances greater than two feet, are also capable of equally distinct vision at distances considerably within that limit. Thus, most eyes are capable of distinct vision at the distance of eight or ten inches, and many at even

less distances. It must therefore be inferred either that there is in the eye such a power of voluntary change, as is sufficient to vary its convergent power on the light transmitted through it, so as to bring forward to the retina the foci of rays diverging from points at eight or ten inches from it, or, that it is so constituted as to bring all pencils, which have a divergence less than those proceeding from objects at eight or ten inches distance, to an exact focus on the retina, without any change in its form or in the state of its humours.

There is, perhaps, no point in physical science upon which more diversity of opinion has prevailed than this. Some eminent physiologists, among whom may be named De la Hire, Haller, Magendie, Simonoff, and Treviranus, have absolutely denied, as a matter of fact, that the eye does undergo any change of form or state in looking at distant and near objects; and the last-mentioned of these philosophers has professed to demonstrate that such a constitution of the humours is possible as would cause all the pencils, whose divergence varies within the supposed limits, to come to a focus on the retina. Not only, however, has the validity of the reasoning by which Treviranus supports his hypothesis been called in question, but it has been demonstrated, as a matter of fact, that the state of an eye which sees distinctly objects at eight inches or less distance, is different from the state of the same eye when it sees distinctly objects at distances exceeding two or three feet. This has been established by various experiments.

906. If we close one eye, and place two pins in the direction of the axis of the other, one at eight inches and the other at twenty-four inches distance, so as not actually to intercept each other, it will be found that the eye cannot see distinctly both pins at the same time, but that by a voluntary act it can render the vision of one or the other distinct. If by this voluntary effort the more distant pin is seen distinctly, the nearer pin will be indistinct, and if, on the other hand, the nearer pin be seen distinctly, the more distant pin will be indistinct. It is clear, therefore, that the convergent power of the eye is varied, so that in the one case it brings rays which are sensibly parallel to a focus on the retina, while the focus of rays sensibly divergent is behind the retina; and that in the other case, the latter rays are brought to a focus upon the retina, while the focus of the former is in front of it.*

* See Handbook Nat. Phil., Optics, § 335, et seq.

907. **The Visual Magnitude**, or apparent magnitude, is the angle formed by the visual lines drawn to the extreme limits of the object. Thus, visual differs from real magnitude, the latter being measured by lines, while the former is measured by angles. The visual magnitude of an object varies with the distances of the observer from it, inasmuch as every increase of that distance causes a proportionate decrease of the visual angles, and *vice versâ*.

Objects having very different real magnitudes may, therefore, have the same visual magnitude. This will occur if their distances from the eye be in the exact ratio of their linear dimensions.

The sun and moon present a remarkable example of this.

The minor limit of the visual angle capable of being distinctly perceived varies with the colour of the object and the intensity of its illumination.

Plateau affirms that a white disc, the sun shining fully upon it, will be visible when seen under a visual angle of twelve seconds, or the one-fifth part of a minute. The disc would subtend this angle at the eye if placed at a distance equal to 17250 times its diameter.

He says also that if the disc were red, it would be distinctly seen until its apparent magnitude were reduced to twenty-three seconds; and that if it were blue, the limit would be twenty-six seconds; but that, if instead of being illuminated by the direct solar light, it were illuminated by the light of day reflected from the clouds, these limiting angles would be half as large again.

908.—**The Minuteness of the Ocular Pictures** which produce distinct vision is truly astonishing.

If we look at the full moon on a clear night, we perceive with considerable distinctness, by the naked eye, the lineaments of light and shade which characterise its disc. Now let us consider only for a moment, what are the dimensions of the picture of the moon formed on the retina, from which alone we derive this distinct perception. The disc of the moon subtends a visual angle of half a degree, and consequently, according to what has been explained, the diameter of its picture on the retina will be $\frac{1}{230}$th part of an inch, and the entire superficial magnitude of the image from which we derive this distinct perception is less than the $\frac{1}{52900}$th part of a square inch; yet within this minute space we are able to distinguish a multiplicity of still more minute details. We perceive, for example, forms of light and shade, whose linear dimensions do not exceed one tenth part of the apparent diameter of the moon, and which therefore occupy upon the retina a space whose area does not amount to the $\frac{1}{5000000}$th part of a square inch.

909. To take another example, the figure of a man 70 inches high, seen at a distance of 40 feet, produces an image upon the retina the height of which is about one fourteenth part of an inch. The face of such an image is included in a circle whose diameter is about one-twelfth of the height, and therefore occupies on the retina a circle whose diameter is about the $\frac{1}{170}$th part of an inch; nevertheless, within this circle, the eyes, nose, and lineaments are distinctly seen. The diameter of the eye is about one-twelfth of that of the face, and therefore, though distinctly seen, does not occupy upon the retina a space exceeding the $\frac{1}{4000000}$th of a square inch.

If the retina be the canvas on which this exquisite miniature is delineated, how infinitely delicate must be its structure to receive and transmit details so minute with such marvellous precision; and if, according to the opinion of some, the perception of these details be obtained by the retina *feeling* the image formed upon the choroid, how exquisitely sensitive must be its touch!

910.—**Sufficiency of Illumination** is as necessary to distinct vision as a well-defined ocular picture. Thus it is possible to conceive a picture on the retina, so extremely faint as to be insufficient to produce sensation, or, on the other hand, so intensely brilliant as to dazzle the eye, to destroy the distinctness of sense, and to produce pain.

When we direct the eye to the sun, near the meridian, in an unclouded sky, we have no distinct perception of his disc, because the splendour is so great as to overpower the sense of vision just as sounds are sometimes so intense as to be deafening. That it is the intense splendour alone which prevents a distinct perception of the solar disc in this case, is rendered manifest by the fact that if a portion of the solar rays be intercepted by a coloured glass, or by a thin cloud, a distinct image of the sun will be seen.

When we direct the eye to the firmament on a clear night, there are innumerable stars which transmit light to the eye, and which therefore must produce some image on the retina, but of which we are altogether insensible, owing to the faintness of the illumination. That the light, however, does enter the eye and arrive at the retina is proved by the fact, that if a telescope be directed to the stars in question, so as to collect a greater quantity of their light upon the retina, they will become visible.

The eye possesses a certain limited power of accommodating itself to various degrees of illumination. Circumstances which are familiar to every one render the exercise of this power evident.

If a person after remaining a certain time in a dark room, pass suddenly into another room strongly illuminated, the eye suffers instantly a degree of inconvenience, and even pain, which causes the eyelids to close; and it is not until after the lapse of a certain time that they can be opened without inconvenience.

Effects the reverse of these are observed when a person passes from a strongly illuminated room into one comparatively dark, or into the open air at night. For a certain time he sees nothing, because the contraction of the pupil, which was adapted to the strong light to which it had pre-

viously been exposed, admits so little light to the retina that no sensation is produced. The pupil, however, soon dilates, and, admitting more light, objects are perceived which were before invisible.*

911. **Foramen Centrale and Limbus Luteus, or Yellow Spot.**—That part of the retina which immediately surrounds the point of it to which the optic axis is directed, is attended with several circumstances which ought not to be passed over here.

The point where the optic axis meets the retina is the centre of a circular yellow spot, called the *limbus luteus*, the radius of which is about the sixteenth of an inch. In its centre, and therefore at the extremity of the optic axis, is what has the appearance of a minute hole, and has accordingly been called from its discoverer, the *foramen centrale* of Sömmering. It is, however, considered by anatomists that this is not a real opening between the vitreous humour and the choroid, inasmuch as a layer of vascular matter covers it, the opening being only in the medullary substance of the retina at that particular point.

The distance between the foramen centrale and the centre of the embouchure of the optic nerve is about the tenth of an inch; and since the radius of the yellow spot is the sixteenth of an inch, it follows that the edge of the yellow spot is about the twenty-seventh of an inch from the centre of the optic nerve.

Taking the radius of the concave spherical surface formed by the retina to be half an inch, 1° upon it will correspond to the 115th part of an inch; and, consequently, the angle subtended by the semidiameter of the yellow spot at the optical centre of the eye will be 7°, and the angle subtended by the distance between the foramen centrale and the centre of the embouchure of the optic nerve will be $11\frac{1}{2}^\circ$.

The sensitiveness of the retina is not the same at all points. If we direct the optic axis to any point upon a distant object, a certain extent of that object surrounding the point to which the optic axis is directed will be visible, but not with a uniform vividness and distinctness. The point to which the axis is directed will be seen with greatest distinctness, and the surrounding points will be perceived with less and less distinctness, as they are more distant from this central point, until they altogether disappear.

* Handbook Nat. Phil., Optics, § 362.

912. **Field of Vision.**—The extreme mobility of the eye, and the subtle and unconscious action of the will upon it, render it extremely difficult to keep the axis fixed upon a certain point while the visual perception of the surrounding points is attempted to be observed. The moment we desire to ascertain to what visual distance on any side of the central point our perception extends, the optic axis, with the rapidity of thought, directs itself to such points. Nevertheless, by much practice, such self-control can be acquired as will enable an observer to ascertain with some degree of approximation the extent of the *field of vision*, by which term is expressed the circular space surrounding the point to which the optic axis is directed, which includes all the objects which can be perceived by the eye at the same instant.

The circle of the retina surrounding the foramen centrale, which corresponds to this field of vision, includes the entire extent of that membrane which is available for the sense of sight: for, although the range of the eye is really much greater, that extension of its sphere of perception is due to the mobility of the eyeball, by which, as already explained, the optic axis has a play, measured horizontally and vertically, through a considerable angular space.

To determine, by immediate observation, the extent of the field of vision when the optic axis is fixed, let a number of red wafers be attached at short intervals to the circumference of a circle having a whitish ground two feet in diameter, and let a single wafer be attached to its centre. Let the card or pasteboard upon which the wafers are attached be fixed to a vertical wall, so that the central wafer shall be at the level of the eye of the observer standing with his face to the wall. If the observer, closing one eye, the left, for example, stand so that a line drawn from the other eye to the central wafer shall be perpendicular to the plane of the circle, and so that his distance from the wall shall be ten or twelve feet, he will see the entire circle of wafers when the optic axis of his eye is directed to the central wafer. If then he gradually approach the circle, still keeping the optic axis directed upon the central wafer, the circumferential wafers will continue to be visible, but will be gradually less and less distinct. When he approaches to the distance of five feet from the central wafer, a remarkable effect will ensue. Those circumferential wafers which are at and near the right-hand extremity of the horizontal diameter of the circle will suddenly cease to be visible, and a gap will appear in the circle on the right side, extending over a fifth or sixth part of the entire circumference.

If the observer now approach still nearer to the circle, keeping the optic axis still directed to the central wafer, the right-hand wafers will continue to be invisible, until he comes within something less than three feet of the central wafer, when they will suddenly reappear. But upon approaching still nearer, all the circumferential wafers will vanish, the central wafer alone being visible.

To explain these phenomena, it must be observed that at the distance of ten feet the radius of the circle is seen under a visual angle of 5·7°, which corresponds to the 20th of an inch upon the retina. The retinal image of the circle of wafers will therefore be a circle having a radius of the 20th of an inch described round the foramen centrale; it will therefore fall within the yellow spot; and, as in this position the observer sees with considerable distinctness the circumferential wafers, and with perfect distinctness the central wafer, it follows that the sensibility of the retina corresponding to the yellow spot is within this limit sufficient for distinct vision, the central point, however, being the most sensitive and producing the most distinct perception.

As the observer approaches the circle, the diameter of the image on the retina increases in the same proportion, very nearly as the distance of the eye from the centre of the circle diminishes. At the distance therefore of five feet, the radius of the retinal image is increased to the tenth of an inch, and that part of it which is on the side of the nose consequently passes across the embouchure of the optic nerve; and as this corresponds to that part of the circle which in this position of the observer becomes invisible, it follows that that part of the retina which corresponds with the embouchure of the optic nerve is absolutely insensible.

That this is the true explanation of the phenomenon is proved by the fact, that when the observer approaches within less than three feet of the central wafer, the circumferential wafers which were before invisible suddenly reappear. In that case the image of the circle on the retina is so enlarged that its circumference includes within it the entire embouchure of the optic nerve, so that the wafers which at five feet distance projected their images upon the embouchure of the optic nerve, now project them on that part of the retina which lies outside the nerve.

Since the nerves are the only conduits between the organs of sense and the brain, it must have appeared somewhat inexplicable that the foramen centrale, the only point of the retina where practical anatomists were unable to discover the presence of nervous matter, should not only possess visual sensibility, but should be endowed with that power in a higher degree than any other part of the retina. It could not, therefore, be matter of surprise that the result of their observations was received with much doubt, more especially as the nervous fibres are highly microscopic, and might be regarded as probably more and more minute, as their sensibility is more exalted. Careful research in recent years, however, has shown that certain elements of the retina exist in the foramen centrale, or, as it is now called by some anatomists, the fovea centralis. The minuteness, however, of these elements is such, that it is not surprising that they should have escaped the observation of microscopist anatomists.*

* Quain's Anatomy, Sixth Edit. vol. iii. p. 24.

913. **The Limits of Field of Distinct Vision,** while the optic axis has a fixed direction, has not been satisfactorily determined. I find by my own observations that objects comprised within a circle of a foot radius, described round the point to which the optic axis is directed, are visible with sufficient distinctness for all the purposes of vision when the eye is placed at the distance of about six feet from the circle. This would correspond to a visual circle of nearly 20° radius; so that if the optic centre of the eye be supposed to be the apex of a cone whose angle is about 40°, all objects within that cone will be visible at the same moment with sufficient distinctness when the optic axis has the direction of the axis of the cone.

When the eye approaches nearer to such a circle, the objects comprised within it, with the exception of those rendered invisible by the insensibility of the embouchure of the optic nerve, are still seen, but the perception of them is indistinct and unsatisfactory. It is probable, however, that these limits of distinct vision measured from the optic axis as a centre, may be different in different eyes.

Valentin gives the narrow limit of 3° round the optic axis, as the range of distinct vision. This must certainly be an error. He does not state on what authority nor on what kind of experiment or observation his conclusion is based.

A radius of 20° corresponds to about the sixth of an inch upon the retina, and if the conclusion derived from my own observations be correct, it will follow that the portion of the retina available for distinct vision will be a circle described round the foramen centrale as a centre, with a radius of about the sixth of an inch.

914. **Attention Necessary to Perception.**—In enumerating the conditions necessary to ensure the distinct perception of a visible object, we have in what precedes included those only which are strictly optical; there is, however, a mental condition not less necessary to perception than the optical conditions already mentioned. The mind has the power by an act of the will to direct its attention with more or less exclusiveness to certain perceptions or ideas, whether proceeding directly from external objects, or evoked by memory or imagination, in preference to others; and, in such cases, although all the conditions of distinct vision above enumerated may be fulfilled, no distinct perception, or no perception at all, may be produced,

owing to the attention of the mind being diverted to other objects. This is not peculiar to sight, but common to all sensible impressions. When engrossed in thought upon any subject of deep interest, we often have our eyes open and fixed upon external objects, from which the retina receives impressions fulfilling all the conditions of distinct vision, yet we see nothing. Physiologists explain this by stating that the fibres of the optic nerve, although transmitting to the sensorium the action produced upon the retina, fail to produce a perception there because the sensorium is then preoccupied by other thoughts and perceptions. Although this, instead of explaining the phenomenon, is little more than a statement of it, it is the only solution offered of a question which lies upon the confines of physiology and psychology. "But by this faculty of attention, we also analyse what the field of vision presents. The mind does not perceive all the objects presented by the field of vision at the same time with equal acuteness, but directs itself first to one and then to another. The sensation becomes more intense according as the particular object is at the time the principal subject of mental contemplation. Any compound mathematical figure produces a different impression, according as the attention is directed exclusively to one or the other part of it. Thus, in fig. 428, we may in succession have a vivid perception of the whole, or of distinct parts only; of the six triangles near the outer circle, of the hexagon in the middle, or of the three large triangles. The more numerous and varied the parts of which a figure is composed, the more scope does it afford for the play of the attention. Hence it is that architectural ornaments have an enlivening effect on the sense of vision, since they afford constantly fresh subject for the action of the mind."*

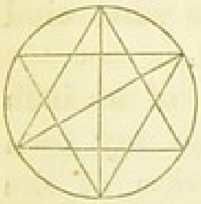


Fig. 428.

915. **Binocular Vision.**—The optical phenomena which we have hitherto considered and explained, are such as would be produced in an observer having a single eye, and, as distinguished from certain others, may be denominated *monocular*; the peculiar phenomena depending on the simultaneous vision with two eyes being called *binocular*.

This being, however, a point which belongs more properly to optics than to physiology, and one which cannot be satisfac-

* Müller's "Physiology," vol. ii., p. 1179.

torily explained with the brevity necessary for our present purpose, we must refer the reader for information upon it to our Handbook of Natural Philosophy, Optics, § 404 et seq.

916. **Perception of Colours.**—The immediate impressions received from the sense of sight are those of light and colour. The impressions of distance, magnitude, form, and motion, are the mixed results of the sense of sight and the experience of touch. Even the power of distinguishing colours is not obtained immediately by vision, without some cultivation of this sense. The unpractised eye of the new-born infant obtains only a general perception of light; and it is certain that the power of distinguishing colours is only acquired after the organ has been more or less exercised by the varied impressions produced by different lights upon it. It would not be easy to obtain a summary demonstration of this proposition, from the experience of infancy, but sufficient evidence to establish it is supplied by the cases in which sight has been suddenly restored to adults blind from their birth. In these cases, the first impression produced by vision is, that the objects seen are in immediate contact with the eye. It is not until the hand is stretched forth, so as to ascertain the absence of the objects seen from the space before the eye, that this optical illusion is dissipated.

The eye which has recently gained the power of vision cannot at first distinguish one colour from another, and it is not until time has been given for experience that either colour or outline is perceived.

917. **Colour-Blindness.**—Besides that imperfection incident to the organs of sight, arising from the excess or deficiency of their refractive powers, there is another class, which appears to depend upon the quality of the humours, through which the light proceeding from visible objects passes before attaining the retina. If these humours be not absolutely transparent and colourless, the image on the retina, though it may correspond in form and outline with the object, will not correspond in colour, supposing the nerves and sensorium to be in a healthy state; for if the humours be not colourless, some constituents of the light proceeding from the object will be intercepted before reaching the retina, and the picture on the retina will accordingly be deprived of the colours thus intercepted. If, for example, the humours of the eye were so constituted as to intercept all the red and orange rays of white light, white paper, or any other white object, such as the sun,

for example, would appear of a bluish-green colour; and if, on the other hand, the humours were so constituted as to intercept the blues and violets of white light, all white objects would appear to have a reddish hue. Such defects in the humours of the eye are fortunately rare, but not unprecedented.

Sir David Brewster, who has curiously examined and collected together cases of this kind, gives the following examples of these defects:—

A singular affection of the retina, in reference to colour, is shown in the inability of some eyes to distinguish certain colours of the spectrum. The persons who experience this defect have their eyes generally in a sound state, and are capable of performing all the most delicate functions of vision. Harris, a shoemaker at Allonby, was unable from his infancy to distinguish the cherries of a cherry-tree from its leaves, in so far as colour was concerned. Two of his brothers were equally defective in this respect, and always mistook orange for grass-green, and light green for yellow. Harris himself could only distinguish black and white. Mr. Scott, who describes his own case in the "Philosophical Transactions," mistook pink for a pale blue, and a full red for a full green. All kinds of yellows and blues, except sky-blue, he could discern with great nicety. His father, his maternal uncle, one of his sisters, and her two sons, had all the same defect.

A tailor at Plymouth, whose case is described by Mr. Harvey, regarded the solar spectrum as consisting only of yellow and light blue; and he could distinguish with certainty only yellow, white, and green. He regarded indigo and Prussian blue as black.

Mr. R. Tucker described the colours of the spectrum as follows:—

Red mistaken for	brown.
Orange ,,	green.
Yellow sometimes	orange.
Green ,,	orange.
Blue ,,	pink.
Indigo ,,	purple.
Violet ,,	purple.

A gentleman in the prime of life, whose case I had occasion to examine, saw only two colours in the spectrum, viz., yellow and blue. When the middle of the red space was absorbed by a blue glass, he saw the black space with what he called the yellow on each side of it. This defect in the perception of colour was experienced by the late Mr. Dugald Stewart, who could not perceive any difference in the colour of the scarlet fruit of the Siberian crab, and that of its leaves. Dr. Dalton was unable to distinguish blue from pink by daylight; and in the solar spectrum the red was scarcely visible, the rest of it appearing to consist of two colours. Mr. Troughton had the same defect, and was capable of fully appreciating only blue and yellow colours; and when he named colours, the names of blue and yellow corresponded to the more and less refrangible rays; all those which belong to the former exciting the sensation of blueness, and those which belong to the latter the sensation of yellowness.

918. **Case of Dr. Dalton.**—In almost all these cases the different prismatic colours had the power of exciting the sensation of light, and giving a distinct vision of objects, excepting in the case of Dr. Dalton, who was said to be scarcely able to see the red extremity of the spectrum. He endeavoured to explain this peculiarity of vision, by supposing that in his

own case the vitreous humour was blue, and therefore absorbed a great portion of the red and other least refrangible rays. That this opinion was erroneous, however, was proved by the *post mortem* dissection of the eyes of that eminent person, by which it appeared that the vitreous humour was perfectly transparent and colourless.

Sir John Herschel attributes the defect of Dr. Dalton's vision, and other defects of the same class, to a morbid state of the sensorium, by which it is rendered incapable of appreciating exactly those differences between rays, on which their colour depends.*

919. **The Visual Organs of Inferior Animals** are subject to considerable variety of form, structure, and position, but may be grouped in three classes :—1st. Eyes formed with transparent media, by which the visual rays are refracted to foci, so as to form images. 2nd. Compound eyes, also furnished with transparent media receiving light from different objects or from different parts of the same object. 3rd. Simple eyes, or *eye-dots*, which appear to possess no other visual faculty except that of distinguishing light from darkness, as if a piece of horn or ground glass were placed before the eyes of the superior animals.

920. **Vertebrata.**—The optical structure of the eyes of this division of the animal kingdom, while it is more or less analogous to that of the human organ, is subject, nevertheless, to great variety in its details. The eyelids are in some cases altogether absent, the skin covering the eye,—as, for example, in the proteida among the amphibia, and the pipa among fishes. The skin sometimes forms a sort of circular zone with a central opening, as in the chameleon. Besides the eyelids analogous to those in the human organ, there is in some animals a third, called the *membrana nictitans.* This is fully developed in birds and reptiles, and exists in a less perfect state in certain genera of the shark family among fishes. In birds this is a semi-transparent membrane, which can be drawn from the inner corner over the entire surface of the eye by means of an appropriate muscular apparatus.

921. **The Lachrymal Apparatus** is absent in cetacea, amphibia, and fishes. The sclerotic in some animals has a tendency to become cartilaginous, and even bony. In birds, tortoises, and lizards, this membrane on the borders of the cornea is supplied with a ring of bony plates, the edges of which either overlap one another or are placed in close apposition. The sclerotic of fishes consists generally of two large coats of cartilage.

* Handbook Nat. Phil., Optics, § 443.

922. **The Choroid** in animals is divisible into two laminæ, the external and internal. The inner surface of the choroid is covered with the membrana pigmenti, consisting of flattened cells, usually hexagonal, containing granules of pigment. In albinos the cells are destitute of pigment. In some animals this membrane is deficient at certain parts of the eye, which have then either a metallic lustre or are white. This part of the internal surface of the eye is called the *tapetum*. The metallic lustre, or iridescent colour, is explained by the interference of the light reflected from it, and is a phenomenon similar to that produced by mother-of-pearl, and other bodies of laminated structure. The tapetum varies in colour in different animals. In the ox it has a greenish metallic hue ; in the cat a golden yellow ; in the horse a silvery blue, and so on. In carnivorous animals it is perfectly white, and occupies a space accurately triangular at the posterior surface of the eye.

923. **The Iris,** in most animals, is contractile, as in man ; but in bony fishes is not perceptibly so.

924. **The Pupil** is sometimes round, as in the human eye ; sometimes elongated transversely, as in ruminants ; sometimes vertically, as in the cat family and the crocodile ; sometimes angular, as in the brown or fire toad.

925. **The Pecten, or Marsupium,** is a pyramidal plicated process from the choroid coat. Passing through an opening in the retina in the bottom of the eye into the middle of the vitreous humour, it follows the direction of the borders of the crystalline. It is characteristic of the class of birds.

926. **The Microscopic Structure of the Retina of Animals** has been recently investigated by Treviranus, Gottsche, and others. This membrane is found to consist of three principal layers : an external, pulpy, and granulated ; a middle, fibrous ; and an internal layer consisting of erect cylinders, being a continuation of the middle or fibrous layer. On entering the eye, the optic nerve divides into cylindrical nervous fibres, which radiate over the middle fibrous layer. Each of these fibres at a certain part of its course turns at right angles to its direction, and terminates in a papilla, so that the combination of all these fibres forms a papillary surface over the entire retinal coat of the eye.

A section of the retina of the hooded crow (corvus cornix) is shown in fig. 429, where *a* is the internal lamina of the choroid ; *b*, the first layer, is

a cellular tissue in which the fibres of the retina radiate; *c*, these fibres turned at right angles to their course, as already described; *d*, the second layer, of cellular tissue; *e*, the larger nervous fibre; *f*, the third layer, perforated by the papillæ *g*, in which the nervous fibres terminate.

The retinal fibres here described vary in their magnitude in different species. The following are the diameters of the species indicated in millionths of an inch:—

Hedgehog fibres	40
Rabbit papillæ	132
Birds' papillæ	80 to 160
Frogs' fibres	176
Ditto papillæ	264

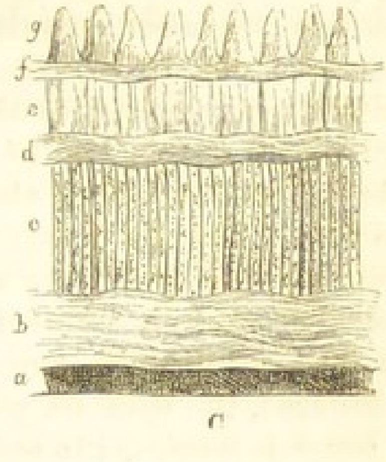


Fig. 429.

SECTION OF THE RETINA OF A HOODED CROW (Treviranus).

927. In animals which seek their prey by night, the eyes are generally larger than those which obtain their nourishment by day. The structure of the pupil in the former differs from that of the human eye, which in contracting or expanding still retains its circular form. It would appear that the degree of play necessary for the pupil of nocturnal animals cannot be obtained by a system of radiating muscles. The pupil, therefore, in these species in contracting assumes an elliptical form, which under the extreme action of the muscles is reduced to a narrow cleft crossing the iris like a button-hole. It is by this expedient that the retina is defended from the injuriously intense action of light during the day, while the fully expanded circular pupil admits sufficient light at night to produce a sensible effect upon it.

928. It will be remembered that the refracting power of the humours of the eye depends, not alone upon their own density and form, but also upon the density of the surrounding medium. According as the latter is increased or diminished, the refracting power of the organ of vision must necessarily also be increased or diminished. It will therefore be apparent that the refracting power of the eyes of animals which live in water requires to be greater than that of animals living in the atmosphere, in the same proportion as the refracting power of water is greater than that of air. In accordance with this, it is found that the crystalline lens in aquatic animals is much more convex than in land animals, and consequently the refracting power of the eye is proportionally greater.

929. In most mammifers the eyes are so mounted in sockets that the direction of the optic axis in their normal position is more or less lateral, so that they can never be directed both to the same object, being always divergent. One of the distinguishing characteristics of human vision is the direction of the optic axes, which, in their normal position are parallel to each other, horizontal, and at right angles to the axis of the body. No part of the economy so obviously indicates the erect position as this. It is only when man stands erect that he can look before him without any extraordinary effort. As we descend in the scale of organisation we find that, as intelligence is lowered, the eyes are placed more and more laterally, so that, in several species, the sphere of vision of each eye is wholly different from that of the other, and it would seem that, in some cases, the animal is altogether incapable of looking before it.

930. **Birds** have the sense of sight highly developed. The eyes are proportionally larger than in mammifers, and supplied with certain supplementary arrangements. The retina is thick, and connected with the crystalline by means of the pecten (925). The pupil is always round, and the cornea large.

That this class is endowed with extraordinary powers of adaptation to vision, at all distances, is certain ; but on what provision this power depends has not been ascertained. The sclerotic is strengthened in front by the zone or hoop of bony plates, already mentioned, surrounding the cornea. The eyelids, as already stated, are triple—two being horizontal, and opening with a vertical motion as in mammifers, and the third vertical, opening with a horizontal motion. The latter is placed at the internal angle of the eye, and is capable of covering the entire surface of the organ. It is semi-transparent. Of the two horizontal eyelids, the inferior, contrary to the disposition in mammifers, is the larger and more mobile.

931. The optical structure of the eye of different species of birds is adapted in the most admirable manner to their varied wants. Thus, in the case of birds of more limited flight, the mechanism is not furnished with any special provision to enable them to see distinctly at a greater distance than their habits render necessary. In the case, however, of those which rise into higher regions of the air, and whose prey is confined to the surface of the ground, nature has provided a special apparatus by which, at will, the bird can render its eye telescopic, so as to distinguish perfectly

its minute prey on the ground from heights so great, that the bird itself, though voluminous, is scarcely distinguishable to human vision. Nevertheless, so distinct and sure is its vision that it drops upon its prey with the most unerring precision. With such species the crystalline is less dense and convex than with birds of more limited flight, and the power of the eye to confer upon itself this long sight, is supposed to depend upon the motor muscles, which, acting upon the bony hoop of the sclerotic, compress the humours with which the organ is filled, or, on the contrary, by their relaxation, relax them. In the one case, the cornea is rendered more, and, in the other case, less convex, so that the focal length of the eye is increased or diminished at will, within very wide limits.

The power of expanding the pupil by admitting a larger pencil of rays to the crystalline, and probably that of advancing the pecten already mentioned, are combined with this in producing the desired effect.

932. **Reptiles** have often, like birds, three eyelids, though sometimes, as in the case of serpents, there are none. The eyeball is then, as in fishes, only covered by a semi-transparent conjunctiva. With most of them the lachrymal glands are rudimentary. The form of the crystalline varies with the habits of the animal, being more convex with aquatic reptiles, than with terrestrial. With some reptiles the pecten of birds is found in a rudimentary state. Some inferior reptiles, such as the proteida and cæcilians, which live in the water of obscure caves, or which hollow for themselves holes in dark and humid places, have rudimentary eyes, consisting of a capsule filled with a transparent liquid, lined internally by a sort of retina, and covered with a pigment on the external surface, from which only the part of the capsule directed to the surface is free. The eyes are hidden under the integuments in the middle of a subcutaneous cellular tissue. These animals can only have very imperfect sight.

933. **The Eyes of Fishes** are large and very slightly moveable, having neither eyelids nor a lachrymal apparatus. The skin passes over them, and is sufficiently transparent to allow light to pass through it. The cornea has but little curvature, the pupil being large, with little contractile power, and the crystalline spherical.

A remarkable anomaly in the position of the eye is presented

in the case of soles and flat-fish, these organs being placed not as usual, one at each side of the head, but both at the same side. This however, is quite in accordance with a similar want of symmetry in other parts of the body of these species.

934. **Annulata.**—Insects and crustacea have compound eyes, consisting of an agglomeration of a vast number of conical tubes, radiating from a centre, and terminating at the external part of the organ so as to form a spherical surface of greater or lesser extent. These cones are terminated at their external surface by little corneæ of polygonal and generally hexagonal forms. Each of them includes in its interior a humour analogous to the vitreous humour of the human eye, and receives a nervous filament at the internal extremity. Their inside surface is coated with dark pigment. Each eye, although its diameter does not usually exceed a minute fraction of an inch, is composed of a vast number of these polygonal tubes, sometimes so many as from ten to twenty thousand. The cornea itself, which covers the external ends of these tubes is coated at its edges with the same opaque pigment which lines the sides of the tube itself, the middle part only being transparent.

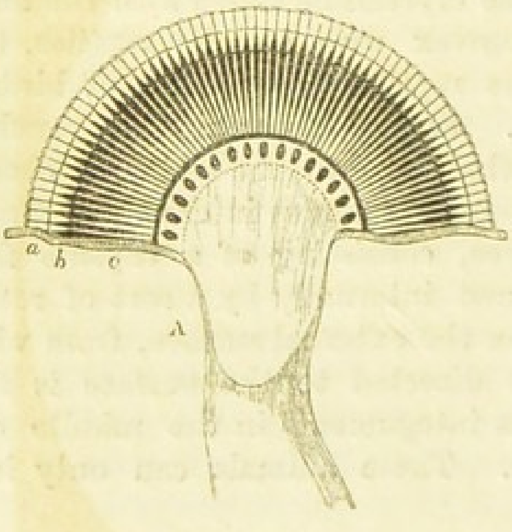


Fig. 430.
SECTION OF THE EYE OF THE COCKCHAFER (Strauss Durckheim).

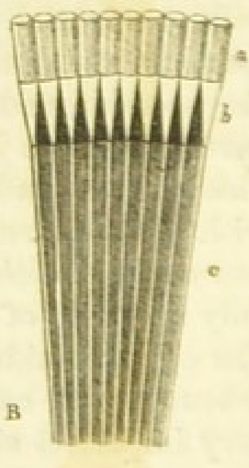


Fig. 431.
SEGMENT OF THE SAME EYE (Müller.)

935. To illustrate the structure of these compound eyes, we give in fig. 430, after Strauss Durckheim, a section of the compound eye of a species of beetle (melolontha vulgaris), where the facets of the cornea are

shown at *a*. The parts supposed by Strauss to be enlarged extremities of the nervous fibres, but shown by Müller to be transparent cones surrounded with pigment, appear at *b;* the fibres of the optic nerve at *c;* and the trunk of the nerve at *d*. A section of the same, more highly magnified, is given after Müller in fig. 431, where the prismatic segments or facets of the cornea are shown at *a;* the transparent conical crystalline bodies at *b;* and the fibres of the optic nerve at *c*.

In fig. 432, the membrane forming the cornea of the compound eye of a common house-fly is shown, magnified 100 times its lineal dimensions.

936. According to the observations of various eminent naturalists, such as Swammerdam, Leeuwenhoeck, Barter, Reaumur, Lyonnet, Paget, Müller, Strauss, Dugès, Kirby, and others, the following are the number of eyes in certain species :—

NUMBER OF EYES.

The ant and xenos	50	The Goat moth	11300
The Sphynx	1300	The dragonfly	12544
The common fly	4000	The butterfly	17355
The silkworm	6236	The mordella	25088
The cockchafer	8820		

937. **Arachnida.**—The eyes of this class are constructed

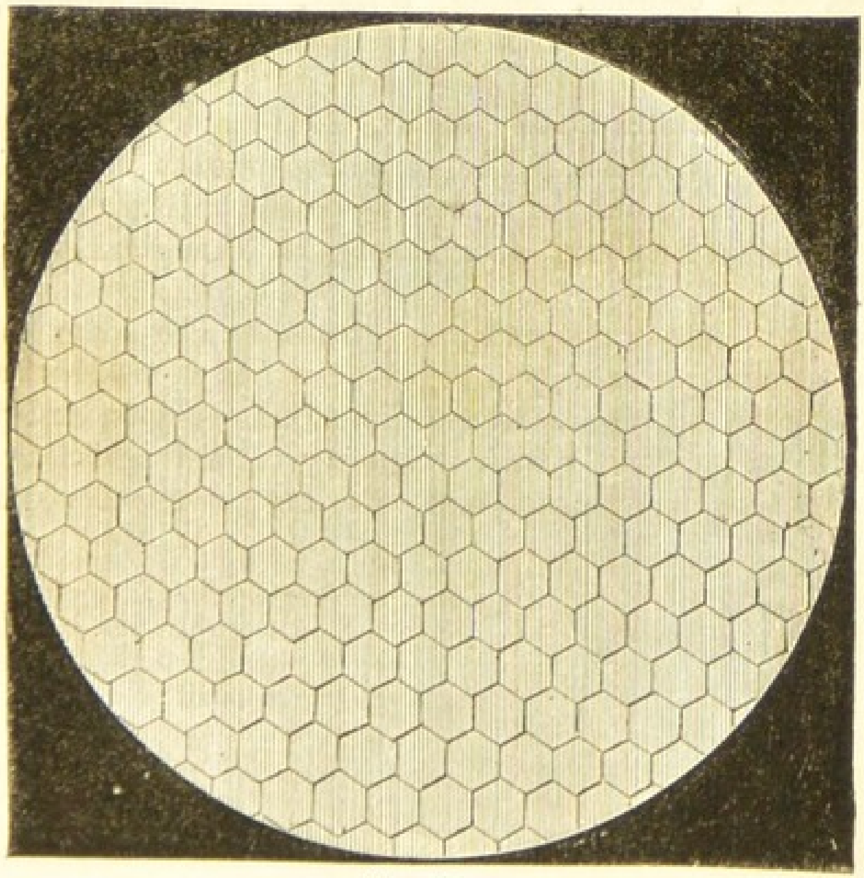


Fig. 432.

upon the same general principles as those of the vertebrata, but consisting of parts having very different forms.

The organ may be illustrated generally by the eye of the scorpion, shown in fig. 433.

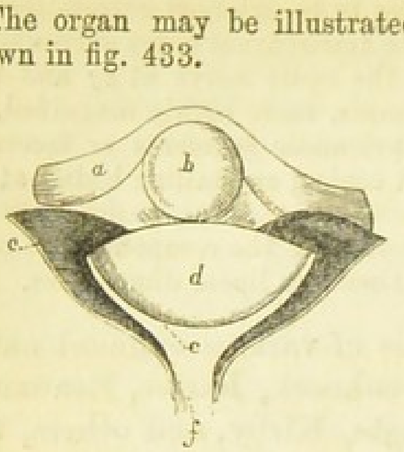


Fig. 433.

SECTION OF THE EYE OF A SCORPION MAGNIFIED (Müller).

In many insects, and in some crustacea, compound and simple eyes coexist. The simple eyes, three or four in number, are then generally placed at the summit of the head, between the two compound eyes. It is probable that the simple eyes are used only for the vision of near objects, and especially to distinguish food, while the compound eyes direct the animal in its movements.

Behind the cornea *a* is a spherical lens, *b* representing the crystalline, and behind this the vitreous humour *d*, having a lenticular form surrounded by the choroid *c*, and resting on the retina *e*, having a cup-shaped form, and being the continuation of the optic nerve *f*.

938. **The Molluscous Cephalopods** have eyes analogous to those of the superior animals. The poulp and the cuttle-fish have two large eyes lodged at the sides of the head, composed of sclerotica, choroid, retina, cornea, vitreous humour, and crystalline lens, with rudiments, occasionally, of eyelids.

939. **The Gasteropods** (snails, &c.) have eyes supported upon salient peduncles. They are less perfect than the preceding, consisting only of a vesicle coated with pigment, filled with vitreous humour, and having a transparent point in front.

Some molluscous acephala, and probably also some radiata, present upon certain points of the body vesicles coated with pigment, which are sometimes called eye-dots, and which endow them apparently with the power of distinguishing light from darkness, but not properly with any powers of vision.

CHAPTER XVI.

HEARING.

940. The eye is so evidently adapted to the properties of light, and the purpose which each of its parts is destined to fulfil can be so clearly demonstrated, that a like conformity might naturally be expected between the form and structure of the ear and the physical properties of sound. Nevertheless, with one or two exceptions, the peculiar and complicated form of the organ of hearing has not been hitherto shown by any satisfactory or conclusive reasoning to be related to the principles of acoustics.

941. **The Ear** consists of three distinct compartments, differing extremely from each other in their form. They are named by anatomists according to their order—proceeding from without inwards—the *external*, *middle*, and *internal* ear.

942. **The External Ear.**—The part of this division of the organ visible on the outside of the skull, behind the joint of the lower jaw, is called the *pinna* or *auricle.*

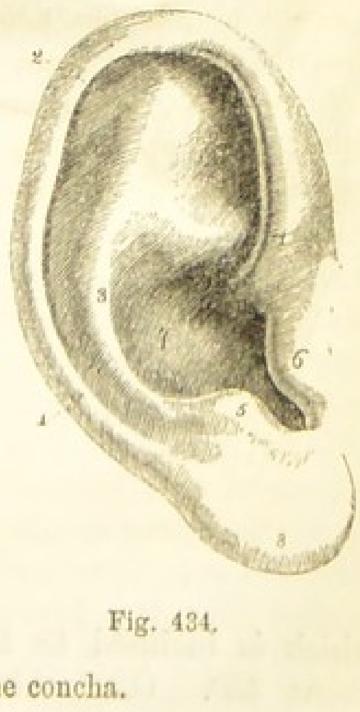


Fig. 434.

The several parts marked in the figure by the numbers 1, 2, 3, &c., are distinguished by specific names in anatomy. With the exception, however, of the cavity 7, called the *concha*, none of these parts can be considered as having any important acoustic properties. The depression, 2, called the fossa of the helix, and the surrounding cartilage, 1, called the helix, may possibly have some slight effect in reflecting the rays of sound towards the concha, 7, and thence into the interior of the ear. If such, however, were the purpose, it would be much more effectually answered by giving to this part of the organ a form more closely resembling that of the wide end of a trumpet. As the external ear is actually constructed, the only part which answers this purpose is the concha.

943. **External Meatus.**—Proceeding inwards from the concha, the remainder of the external ear is a tube something more than an inch long, the diameter of which becomes rapidly smaller; its calibre is least about the middle of its length, being slightly augmented between that point and its connection with the middle ear. Its section is everywhere elliptical, but in the external half the greater diameter of the ellipse is vertical, and in the internal, horizontal. This tube does not proceed straight onwards, but is twisted so that the distance from the concha to the point where it enters the middle ear is less than the total length of the tube. The external part of the tube is cartilaginous like the external ear, but its internal part is bony; the bony surface, however, being lined by a prolongation of the skin of the auricle.

944. **Membrane of Tympanum.**—The internal extremity of this tube is inserted into an opening leading into the middle ear,

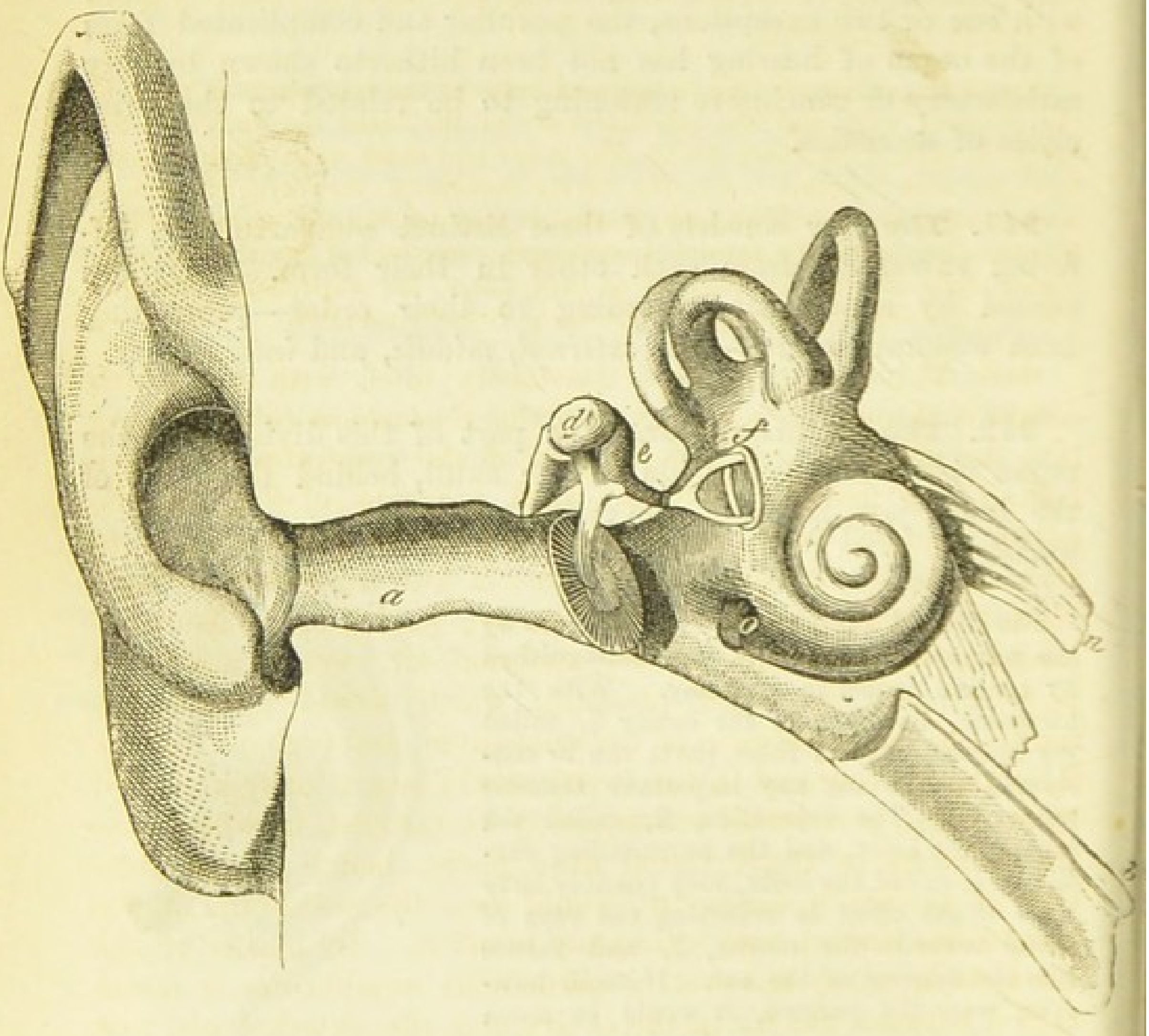


Fig.435.

which is inclined to the axis of the tube at an angle of about 45°. Over this opening, which is slightly oval, an

elastic membrane, called the *membrane of the tympanum*, is tightly stretched, like parchment on the head of a drum.

In fig. 435 the several parts of the ear are shown divested of the surrounding bony matter; and to render their arrangement more distinct, they are exhibited upon an enlarged scale. The concha, with the tube leading inwards from it marked *a*, terminates at the inner end, as already stated, in the tense membrane of the tympanum placed obliquely to the axis of the tube. The resemblance of this tube and the concha to the speaking or hearing trumpet is evident, and the physical purposes which it fulfils are obviously the same, being those of collecting and conducting the sonorous undulations to the membrane of the tympanum, which will vibrate sympathetically with them.

945. **The Middle Ear** is a cavity surrounded by walls of bone, which, however, are removed in fig. 435, to render visible its internal structure.

An opening corresponding to the membrane of the tympanum is made in the external wall, and the external part of the inner ear shown in the figure is part of its inner wall. The inner and outer walls of this cavity are very close together; but the cavity measures, vertically as well as horizontally, about half an inch, so that it may be regarded as resembling the sounding-board of a musical instrument, composed of two flat surfaces, placed close and nearly parallel to each other, the superficial extent of which is considerable compared with their distance asunder.

946. This cavity is kept constantly filled with air, which enters it through a tube, *b*, called the *Eustachian tube*, opening into the pharynx, and forming part of the respiratory passages behind the mouth. Without such a means of keeping the cavity supplied with air, having a pressure always equal to that of the atmosphere, one or other of two injuries must have ensued; either the air in the cavity, having a temperature considerably above that of the external air, would acquire a proportionally increased pressure, which would give undue tension to the membrane of the tympanum, and perhaps rupture it, or the air confined in the cavity would be gradually absorbed by its walls, and would consequently be rarefied, in which case the pressure of the external atmosphere, being greater than that of the air in the cavity, would force the membrane of the tympanum inward, and ultimately break it. By means of the Eustachian tube, however, a permanent equilibrium is maintained between the air in the cavity and the external air, just as is the case in a drum, or in the sounding-board of a musical instrument, where apertures are always provided to form a free communication with the external air.

947. In the inner wall of this cavity there are two prin-

cipal foramina, a greater and a lesser; the former being called, from its oval shape, the *fenestra ovalis*, and the latter the *fenestra rotunda*; the former is shown at *f*, in fig. 435, and the latter at *o*. Over both of these, elastic membranes are tightly stretched, as the membrane of the tympanum is over the inner end of the external meatus.

Between the membrane of the tympanum and the membrane of the fenestra ovalis there is a chain, consisting of three, and in the young of four, small bones articulated together, and moved by muscles having their origin in the bones which form the walls of the cavity.

Three of these bones are shown in fig. 435, at *d*, *e*, and *f*. The first, *d*, is called, from its form, the *malleus*, or hammer; the end of its handle is attached to the membrane of the tympanum near its centre; its head, which is round, is inserted in a corresponding cavity of the second bone, *e*, called the *incus*, or anvil; and the smaller end projecting from this, articulated with the third bone, *f*, called the *stapes*, or stirrup, from the obvious analogy of its form; in the young individual a fourth bone, *orbiculare*, occurs between the two last fig. 437 *c*. The base of this stirrup corresponds in magnitude and form with the fenestra ovalis, in which it is inserted, keeping, as it would appear, the membrane which covers that aperture in a certain state of tension upon it. The handle of the malleus being firmly attached to the centre of the membrane of the tympanum, draws that membrane inwards, so as to render it more or less convex, or rather conical, towards the tympanic cavity.

The muscles which act upon these small bones are supposed to have the property of giving greater or less tension to the two membranes which they connect, so as to render them more or less sensitive to the sonorous undulations propagated through the external ear. When the sounds are loud the muscles render the membranes less sensitive, and when they are low they render them more so. According to this supposition, when we listen attentively to low sounds, we not only concentrate the attention of the mind upon them, but we also act upon the nerves which govern the muscles inserted in the chain of auricular bones, and thereby increase the sensitiveness of the organ.

It must be observed, however, that this is a mere hypothesis, no such action of these bones and muscles having been established as a matter of fact.

948. The use of the auricular bones is supposed to be the transmission of the pulsations imparted by the sonorous undulations from the membrane of the tympanum to the membrane of the fenestra ovalis. It has been ascertained, however, that if the membrane of the tympanum were altogether destroyed, the sense of hearing would still remain, though it would not be so perfect. It must therefore be inferred that the auricular bones are not the only means of transmitting the sonorous

undulations to the internal ear, the air contained in the middle ear being itself sufficient for that purpose.

It cannot be doubted that the membrane which covers the fenestra rotunda has some share in producing the sensation of sound; and, if so, the chain of bones can have no effect upon it, the undulations being merely propagated to it by the air contained in the middle ear.

949. **The Internal Ear.**—We now come to consider the internal ear, which is, in fact, the true and only organ of the sense of hearing, the external and middle ears being merely accessories by which the sonorous undulations are propagated to the fluids included in the cavities of the internal ear.

The internal ear is a most curious, and, as it must be acknowledged, unintelligible organ, also called, from its complicated structure, the *labyrinth*. Its channels and cavities are curved and excavated in the hardest mass of bone found in the whole body, called the *petrous* or bony part of the skull. It is shown in fig. 436, as if all the surrounding mass of bone except that which forms the immediate surfaces of the cavities were cut away.

950. **The Labyrinth** consists of three distinct parts, called severally the vestibule, the semicircular canals, and the cochlea.

The vestibule is a central chamber excavated in the petrous bone. In its external wall the fenestra ovalis, *f*, is formed, and the auditory nerve, *n*, enters through a foramen in its internal wall.

At the posterior and upper part of this vestibule, are the semicircular canals, consisting of three tabular cavities bent into forms from which their name is taken, and distinguished by anatomists as the interior, posterior, and superior canals, according to their relative positions.

On the interior and anterior side of the vestibule, and near the fenestra rotunda, is the cochlea, consisting of a cavity carved in the bone in the form of a spiral tube,—the name cochlea being given to it from its resemblance to the cavity within the shell of a snail, cochlea being the Latin name of that animal. Both the semicircular canals and the cochlea are in free communication with the vestibule.

951. The auditory nerve arrives at the bony wall of the internal ear through a passage called by anatomists the internal auditory meatus. Before entering the foramen provided for its admission into the internal ear, it separates into two principal branches, one of which is directed to the vestibule and the other to the cochlea, which are thence called, respectively, the *vestibular* and *cochlear nerves*.

Within the three semicircular canals are included flexible

membranous tubes of the same form, called the *membranous canals.* These include within them the branches of the auditory nerve, which pass through the semicircular canals, and they are distended by a specific liquid called *endolymph,* in which the nervous fibres are bathed. The bony canals around these membranous canals are filled with another liquid, called *perilymph,* which also fills the cavities of the vestibule and the cochlea. It appears, therefore, that all the cavities of the internal ear are filled with liquid, and it must, accordingly, be by this liquid that the sonorous undulations are propagated to the fibres of the auditory nerves. The liquid being incompressible, the pulsations imparted either by the auricular chain of bones, or by the air included in the cavity of the middle ear, or by both of these, to the membranes which cover the fenestra ovalis and the fenestra rotunda, are received by the liquid perilymph within these membranes, and propagated by it and the endolymph to the various fibres of the auditory nerve.

This arrangement will be rendered more clearly intelligible by reference to fig. 436, which is a perspective magnified view of the labyrinth,—the canals, vestibule, and cochlea being laid open so as to display their interior.

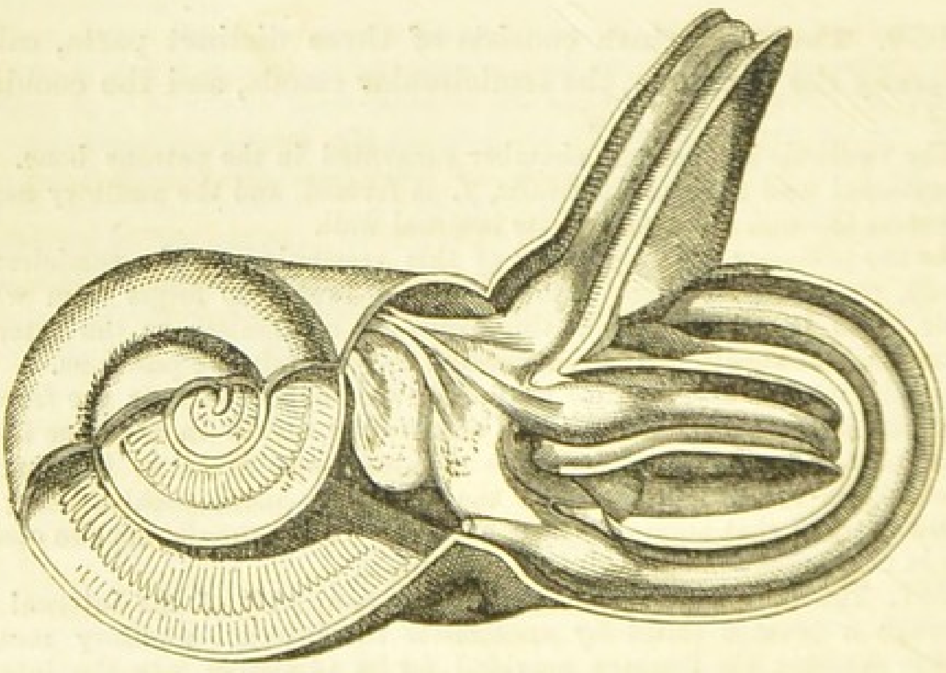


Fig. 436.

The four minute bones already described as connecting the membrane of the tympanum with the fenestra ovalis, are shown separately, in their natural size, at *a*, *b*, *c*, *d*, in fig. 439, and on an enlarged scale in fig. 438.

952. The form of the membrane of the tympanum has been generally considered by anatomists as elliptical. Professor Sappey has submitted a considerable number of cases to measurement, either by means of moulds, by a fresh preparation, or by those preserved in the museum of the Faculty of Medicine in Paris, and has found that the form, if elliptical at all, is so slightly oval as not to be distinguishable from a circle except by very exact measurement. He found that the proportion of two diameters was about that of 20 to 21.

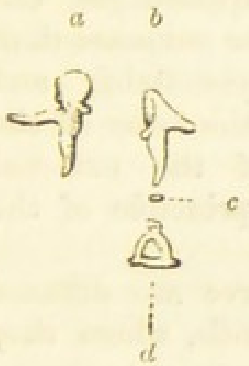


Fig. 437.

a. Malleus.
b. Incus.
c. Orbiculare.
d. Stapes.

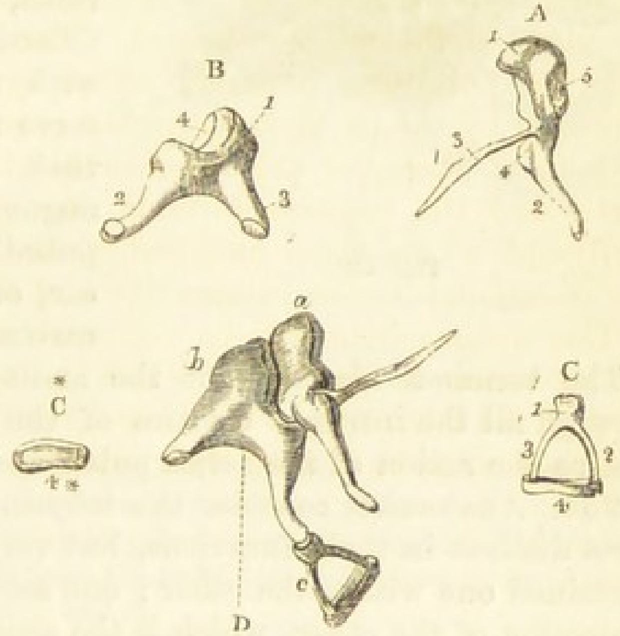


Fig. 438.

BONES OF A TYMPANUM ENLARGED (Arnold).

A. Malleus. 1, head; 2, handle; 3, long process; 4, short process; 5, articular surface.
B. Incus. 1, body; 2, long process; 3, short process; 4, articular surface.
C. Stapes. 1, head; 2, posterior crus; 3, anterior crus; 4, base.
C*. Base of stapes.
D. The three bones in their natural position.

The same bones are shown, in connection with the muscles which move them, in fig. 439; where *a a* is the tympanic cavity, *b* the circle to which that membrane is attached, *c* the handle of the malleus resting on the middle of the membrane, *d* the head of the malleus articulated with the incus, *g*, and *e* the handle of the malleus passing into a cavity called the glenoid fissure, *f* the internal muscle of the malleus, *h* the orbicular bone, *i* the stapes, *k* the muscle of the stapes.

The two muscles *f* and *k* are the provisions by which the necessary tension is imparted to the two membranes.

The membrane of the tympanum is concave outwards in man and other mammalia, but convex in birds. Sometimes the

concavity is confined to its central part, but in general extends to its edges, its shape being that of a cone rounded at its summit, the diameter of whose base is four-tenths, and whose height is four-fiftieths of an inch.

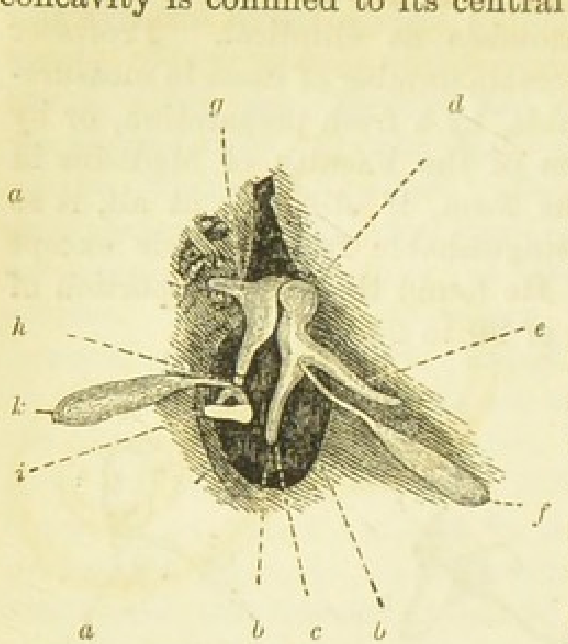


Fig. 439.

953. **The Auditory Nerve** being confined to the labyrinth, it is evident that the external and middle ears, with their appendages, can serve no other purposes than that of transmitting and augmenting the force of the pulsations of the external ear, on the principle of the ear-trumpet.

The terminal filaments of the auditory nerve are diffused through all the intricate cavities of the labyrinth, where they receive the action of the aerial pulsations transmitted to them.

954. Anatomists consider the labyrinth as consisting of two parts distinct in their functions, but very similar in their form, contained one within the other; one serving as a sheath for the protection of the other, which is the sensitive part.

The Osseous, or Bony Labyrinth, is composed of the hardest part of the petrous bone, and is perfectly smooth on its inner surface, every part being moulded to the form of the sensitive part which it is desired to protect.

The Membranous Labyrinth is included within the osseous labyrinth, and includes within it the filaments of the auditory nerve, which enter through several foramina in the bony labyrinth from the internal auditory meatus.

The external form of the bony labyrinth is shown in its natural size in fig. 440, and magnified, so as to render its parts more distinctly visible, in fig. 441.

955. **Semicircular Canals.**—Although the term semicircular has been applied to the three canals, their forms do not correspond to semicircles. They are irregularly curved, and their extremities approach each other so as to give them more the character of complete circles than that of a semicircle. At one extremity each of these tubes is considerably enlarged, forming a sort of ball, as shown at the parts marked *. In some species, however, the forms of these parts more

* Sappey, vol. ii. p. 555.

resemble the wide end of a trumpet. The other extremities have no such enlargement. At both extremities they open into the vestibule. Two of them, marked 3 and 5 in the figure, unite at their narrow extremities, so

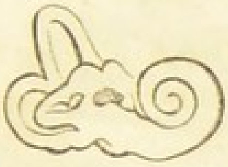


Fig. 440.
BONY LABYRINTH IN ITS NATURAL SIZE.

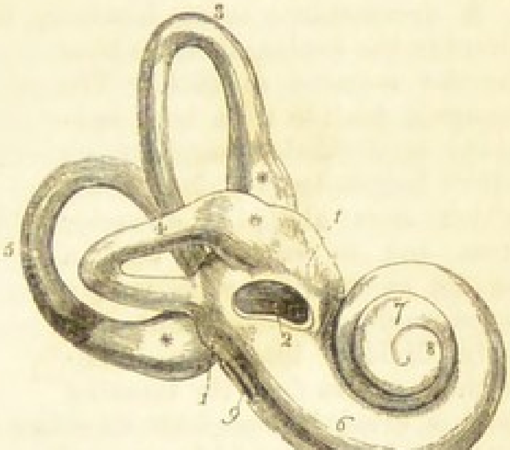


Fig. 441.
DITTO MAGNIFIED (Sömmerring).

1. Vestibule.
3, 4, 5. Semicircular canals.
6, 7, 8. Cochlea.
2. Fenestra ovalis.
9. Fenestra rotunda.

as to enter the vestibule by a common embouchure. They communicate, therefore, with the vestibule by five embouchures, three of which lead from the three ampullæ—as the enlarged ends of the semicircular tubes are called—and the two others from the small end of the tube 4, and the common extremity of the tubes 3 and 5.

The lengths of these canals are subject to great variation in different individuals. The longest is that marked 5, called the *posterior*. This generally measures in its total length from $\frac{7}{10}$ to $\frac{8}{10}$ of an inch. That marked 3, called the *superior*, measures from $\frac{5}{10}$ to $\frac{6}{10}$, and that marked 4, called the *exterior*, very little less than $\frac{5}{10}$. Individual cases, nevertheless, have been found in which they are much less developed, the length of the longest of them sometimes not exceeding $\frac{1}{10}$ or $\frac{2}{10}$ of an inch.

The general calibre of these tubes is from $\frac{4}{100}$ to $\frac{6}{100}$ of an inch; the transverse diameters of their ampullæ being about twice that magnitude.

956. **The Cochlea.**—It is difficult to convey an exact notion of the form of the helical tube, called the *cochlea*. The best way to obtain a clear conception of it is to imagine, in the first instance, a flexible tube of gradually decreasing calibre, wide at one end and tapering to a comparatively small orifice at the other.

Let a solid cone be then imagined, having an obtuse angle and rounded off at the apex, and let the flexible tapering tube, applied with its wide end at the base of the cone, be rolled spirally round it, so as to describe about two coils and a half in passing from the base to the apex. Now if the

solid cone be imagined to consist of the more porous and spongy part of the cranial bone, and the tube thus coiled round it of the harder and more brittle part, a tolerably exact notion may be obtained of the substance and form of the cochlea.

A circumstance must, however, be noted in its structure, which, to simplify the explanation, we have for the moment omitted. The tapering flexible tube here imagined is divided throughout its entire length by a thin lamina, which runs along its diameter from end to end, so that a section of the tube made at any point would be a circle diametrically divided into two semicircles; and, in fact, the tapering tube is divided throughout its entire length into two parts, each of which, considered alone, would be a tapering semicircular tube, having the flat lamina as its base. In coiling the tube round the cone, it must also be understood that the lamina which thus divides it has everywhere its edge presented to the surface of the cone, so that in passing round the cone it would have the same form and position as the thread of a conical screw. (Fig. 442.)

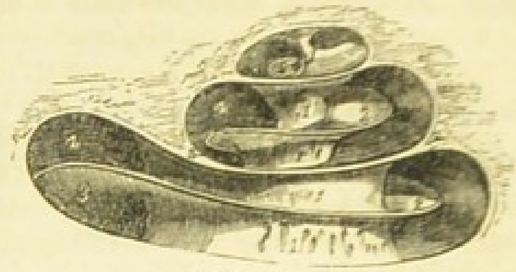


Fig. 442.

This spiral lamina is formed of bony matter through the extent of about $\frac{2}{3}$ of its entire width, measured from its inner edge outwards; the remaining $\frac{1}{3}$, extending to the outer edge of the spiral tube, being membranous.

957. **The Vestibule.**—The cavity of the vestibule is irregularly formed, its extreme length being from $\frac{20}{100}$ to $\frac{25}{100}$, its breadth from $\frac{16}{100}$ to $\frac{20}{100}$, and its thickness from $\frac{12}{100}$ to $\frac{16}{100}$ of an inch.

958. **The Membranous Vestibule** consists of two vesicles, or sacs,—the superior of ovoidal form, called the *utricle;* and the inferior and smaller, of spheroidal form, the *sacculus.*

These, though apparently distinct, are closely connected together. The parts of the membranous labyrinth which are deposited in the semicircular canals are membranous tubes, which correspond with these canals in form, having a diameter about $\frac{1}{3}$ of that of the bony tubes through which they pass. They all open into the utricle by four orifices, one of which is common to two of them. Like the bony canals, they have enlargements at one end, which nearly fill the bony cases.

959. **Endolymph and Otoliths.**—The utricle, sacculus, and the semicircular membranous tubes communicating with them, are filled with *endolymph,* and the utricle and sacculus also contain two small rounded solids, called *otoliths,* which consist of carbonate of lime agglutinated together by mucous and animal matter.*

960. **Perilymph.**—The whole extent of the cavities of the vestibule, and the canals outside the membranous sacs and tubes here described, as well as those of the cochlea, are filled with *perilymph.* In this the membranous sacs and tubes float, without being connected with the bony

* Quain, Sixth Edit. vol. iii. p. 63.

sheaths around them. The perilymph and endolymph are secreted, the one by the membrane which lines the bony tubes, and the other by that which composes the corresponding parts of the membranous labyrinth.

961. **The Acoustic Nerve.**—The acoustic nerve, the filaments of which enter the vestibule through foramina placed at the side opposite to the fenestra ovalis, sends branches into the utricle, the sacculus, and round the three membranous canals, over every part of which they spread themselves. Other ramifications passing into the cochlea spread themselves over the spiral lamina, which divides that tube diametrically. The cavities of the cochlea being filled with perilymph alone, to the exclusion of endolymph, it follows that the nervous filaments there are subject to the action of a fluid different from that to which they are exposed in the vestibule and the canals, where they are bathed, not in perilymph, but in endolymph.

962. **The Distribution of the Acoustic Nerve in the Cochlea** is shown in the section of the cochlea and the bony cone within it in fig. 443 ; where 1 is the auditory nerve, which diverges in the manner shown in the figure, through the interstices of the bony cone round which the cochlea is coiled, entering each coil at the point where the spiral lamina meets it, and then are spread out, as shown at 2 upon the lamina. The central nerve, which ascends to the summit of the cochlea, is shown at 3, and the branch which proceeds to the vestibule at 4.

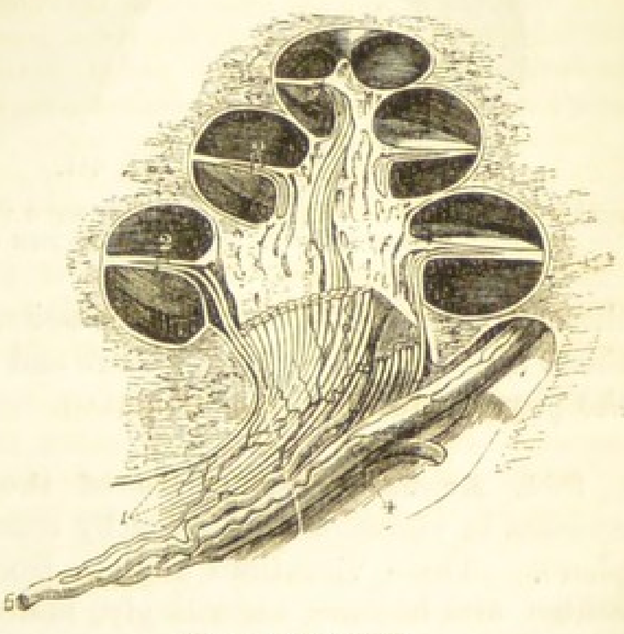


Fig. 443 (Arnold).

A perspective view of the spiral lamina on a magnified scale, with the filaments of the auditory nerve spread over it, and divested of the cochlea, is shown in fig. 444.

963. Having thus fully explained and illustrated the complicated mechanism of the ear, it would be highly satisfactory to be enabled to show how these various forms are connected with the physical laws of acoustics. All the analogies of nature must impress us with the conviction that none of these curious forms have been created without a purpose, and that such purpose can only be to confer the highest attainable perfection upon the sense of hearing. Philosophers have, nevertheless,

not been so happy as to discover the physical relation between

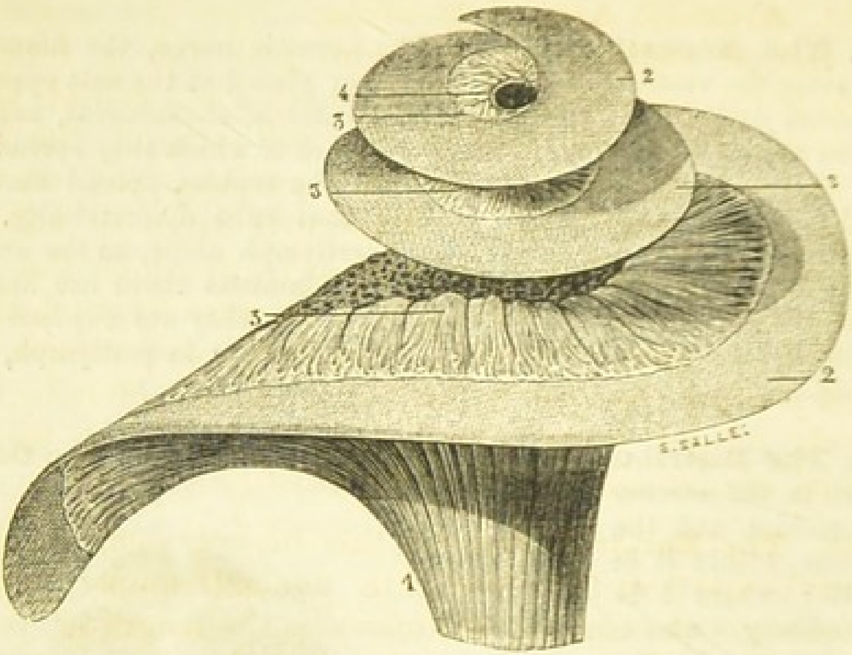


Fig. 444.

PERSPECTIVE VIEW OF THE SPIRAL LAMINA, WITH THE FILAMENTS OF THE AUDITORY NERVE UPON IT, DIVESTED OF THE COCHLEA (Sappey).

these forms and the laws of acoustics, as they have explained those which connect the structure and substance of the eye with the physical properties of light.

964. **Acoustic Properties of the External Ear.**—Sound consists in vibrations imparted by sonorous bodies to the atmosphere. These vibrations radiate from the sonorous body as a centre, and become, accordingly, more and more diffused, and therefore more and more feeble, as the distance from the sonorous body is augmented. Like the rays of light, however, they can be collected and condensed by artificial expedients, one of which consists in receiving a great number of them in the expanded mouth of a tube, like the open end of a trumpet, and by contracting such tube gradually to a small orifice, in which all the rays entering the wide end will be collected together. The loudness of the sound at the narrow end of such a tube will be greater than its intensity at the wide end, in the same proportion as the magnitude of the wide opening is greater than that of the narrow opening. Thus, if the diameter of the wide opening be ten times that of the narrow opening, the magnitude of the former will be a hundred times that of the latter, and the

loudness of the sound at the narrow opening will consequently be a hundred times greater than that at the wide opening.

965. **Artificial Aids to Hearing.**—Now the auricle with the external auditory meatus forms just such a tube. The auricle is the wide opening which receives and collects the rays of sound. It is true that in man all parts of the auricle, are not equally efficient for this purpose, but the concha though not perfectly so, is sufficiently large to collect the necessary number of the sonorous rays, provided the ear has the ordinary degree of sensibility. In cases where individuals lose the necessary degree of sensibility, the concha of the auricle is often enlarged by artificial means. Metallic cavities properly formed being attached to each of the ears, give artificial conchæ enlarged in any desired proportion.

966. **The Ear-trumpet.**—If this be not sufficient, a more powerful expedient is presented in the ear-trumpet, which not only enlarges the concha, but increases the length of the auditory meatus. In this case, the small aperture of the ear-trumpet is reduced to such a size as to allow it to enter the opening which leads to the auditory meatus, so that when thus inserted, the auditory meatus and the tube of the trumpet extending to its wide and expanded end, form one continuous tube, and the wide end becomes a great enlarged artificial concha. The loudness of the sound will thus be augmented in a proportion equal to that of the magnitude of the mouth of the ear-trumpet, or to the magnitude of that part of the concha which has a corresponding efficiency in the collection of the sonorous rays.

967. **The External Ears of Inferior Animals** are in many species more favourable for auscultation than that of the human ear. It will be evident, for example, that the ears formed like those of the horse are better adapted for the collection of sound.

968. **The Theory of the Tympanum** is understood but imperfectly. It is evident, however, that its purpose consists in the propagation of the sonorous vibrations from the external air to the membranes of the fenestræ ovalis and rotunda, and it is probable that it may also have some effects which are not yet fully understood, in modifying the vibrations.

It has been demonstrated by Savart, that a membrane stretched tightly over an opening, as parchment is on a tambourine or drumhead, will be thrown into vibration by a

sound produced near it. If fine sand be sprinkled upon the parchment of a drumhead, it will be agitated and thrown into various forms, the particles jumping upwards, as if they were repelled by the parchment when a sound is produced near it, but no such effect will be found if a piece of card or board be laid upon the same opening, unless a sound of an extreme loudness be produced.

It will also be found that the susceptibility of such a membrane to enter into vibration will vary according as its tension is varied. It is evident, therefore, that in the same manner the membrane of the tympanum will be thrown into vibration by the sonorous pulsations of the external air. These vibrations will be imparted more or less to all objects with which the tympanum is in connection, and so much the more so as these objects are more or less vibratory, and as the tension of the tympanum is more or less intense. A certain portion, therefore, of the vibratory force of the membranes of the tympanum will be imparted to all the masses of bone surrounding the middle ear, and by these to the labyrinth and through it to the auditory nerve, just as a portion of the vibratory force received by the parchment of a drumhead from the drumsticks is transferred to the parchment on the lower drumhead by the wooden sides of the drum.

In like manner a certain portion of the vibratory force of the membrane of the tympanum is transmitted to the membrane of the fenestra ovalis by the chain of bones which connects them, just as a portion of the vibration imparted to the parchment of the upper drumhead is transmitted to that of the lower by the cords and braces which connect the two parchment discs.

These two portions of the vibratory force, however, are as nothing compared to that which is transmitted through the air which fills the cavity of the middle ear, and indeed it may be stated that, for all practical purposes, the air thus included is the sole agent in the transmission of the sound; and hence it is evident how important a part of the auricular mechanism is the Eustachian tube, by which the cavity of the middle ear is supplied with air.

However useful the membrane of the tympanum and its appendages may be, it is not indispensable to the sense of hearing. When it is ruptured, the air in the cavity of the tympanum communicating freely with the air in the external ear, the pulsations of the external ear are propagated to the

membranes of the vestibule without other modification than such as they may receive from the concha and meatus of the external ear; and although the sense of hearing be not as perfect as before, it will not be destroyed.

969. **Use of the Tympanic Bones.**—The use of the chain of bones connecting the membranes of the tympanum and fenestræ, is not perfectly understood. That their sole purpose cannot be to aid in the transmission of sound from the inner to the outer ear is sufficiently apparent. It is certain, meanwhile, that by the contractile power of the muscles connected with them, these bones have the power of varying, within certain limits, the tension of the membranes which they connect. It has, therefore, reasonably been inferred that, by thus varying their tension, these membranes are rendered more or less sensitive; and that a protecting influence is thus brought into operation, by which sounds of excessive loudness are prevented from injuring the organ, while, on the other hand, by augmenting its sensibility sounds are rendered perceivable which would otherwise be unheard.

970. If this hypothesis be admitted, a beautiful analogy will be established between the bones of the tympanum and the iris.

971. **Theory of the Labyrinth.**—The sonorous vibrations imparted by the air included in the cavity of the tympanum to the membranes which are stretched over the two fenestræ, are propagated by the liquids which fill the cavities of the vestibule to the filaments of the auditory nerve. Although these fluids, like all liquids, are inelastic and incompressible, they are, nevertheless, capable of propagating the sonorous vibrations imparted to the membranes in contact with these, as is practically proved by the fact that persons descending to a considerable depth in the sea by means of diving apparatuses, can hear the sounds produced above the surface.

Why, however, the cavities of the labyrinth have been filled with a liquid instead of air or any other gas, has not been explained.

It appears from the experiments of physiologists, nevertheless, that the presence of the liquid with which the labyrinth is filled is an essential condition to the exercise of hearing. The membrane of the tympanum may be ruptured, and the chain of bones removed without producing deafness; but if the mem-

branes of the fenestræ, or either of them, be ruptured so that the perilymph escape, deafness is found to ensue.

972. **Experiments on Imperfect Ears.**—It would have been very satisfactory, in the absence of all explanation of the structure of the labyrinth upon the general principles of acoustics, if the uses of its several parts could have been ascertained by direct experiments, as has been done with relation to different parts of the brain. Of such experiments, however, we are only aware of one, which is due to M. Flourens. That physiologist ascertained that the destruction of the semi-circular canals renders the sense of hearing confused and painful, but does not destroy it.

973. **Structure of the Ears of Inferior Animals.**—As I have already stated, however, no physical conditions yet discovered have explained the peculiar form given to the labyrinth. We know not why two different fluids are there, nor have the acoustic properties of either the utricle or the sacculus or the three semi-circular canals, or, least of all, those of the cochlea, been explained. It is generally assumed, nevertheless, that all the parts which compose the ear are necessary to the perfection of the sense of hearing, although that sense may exist in a less perfect degree in the absence of some of them. We find accordingly that, as we descend in the scale of organisation the accessories of the organ disappear, one by one, in animals which are less and less elevated in the series. With birds, for example, the auricle is altogether wanting, and the external ear is reduced to the auditory meatus. With that class of animals also the cochlea loses its peculiar form, and the tapering tube, instead of being coiled round a cone, is straight, and is proportionally shorter than with superior animals, as will appear by the outline of the bony labyrinth of the barn-owl, shown in fig. 445, where 2 is the vestibule, and 3 the cochlea divested of the spiral form.

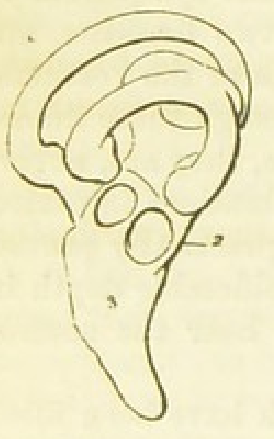


Fig. 445.

974. **Reptiles.**—In reptiles generally the external auditory meatus is wanting, and the ear commences with the membrane of the tympanum which is its exterior part, the structure of the cavity of the tympanum being also simplified.

975. **Fishes.**—In most species of fishes the tympanum and its appendages are wanting, and the ear is reduced to the labyrinth, which consists of a membranous vestibule surmounted by three semi-circular canals, and having below it a little sack which seems to supply the place of the cochlea, in which one or more calcareous bodies, termed otoliths, are suspended. The auricular apparatus is placed in the lateral part of the great cavity of the skull.

976. **Mollusca.**—In descending still lower in the scale of organisation all traces of the semi-circular canals and the cochlea are effaced, and the organ is reduced to a membranous vestibule, which consists of a little sack filled with a liquid in which the last fibres of the acoustic nerve are diffused. Such a vestibule appears to be an essential element of the auditory organ, never being absent so long as that organ exists at all.

With mollusca also the organ of audition is reduced to the vestibule, which consists of a little vesicle placed at each side of the brain including a liquid in which, besides the terminal fibres of the acoustic nerve, are found minute solid corpuscles, which incessantly oscillate, and which are analogous to the otoliths already described.

Crustacea.—In the higher forms of Crustacea, an organ of hearing has been discovered by Dr. Arthur Farre, in the second pair of antennæ.

977. **Insects.**—Although insects do not appear to be altogether insensible to sound, naturalists have not discovered in their structure any special organ of hearing.

The sense of hearing appears to be altogether wanting in zoophytes and other inferior species.

CHAPTER XVII.

VOICE.

978. ANIMALS resort to various expedients for the production of sound. Some sounds are incidental to their organic or locomotive movements ; such are the sounds of the heart, those of the feet or wings in locomotion, those of some moveable parts of the body striking or rubbing against others ; those of respiration, including sounds produced by the occasional propulsion of air through the respiratory passages, such as those attending sighing, yawning, coughing, snoring, &c. Respiration itself, when it proceeds with a certain intensity, becomes audible, especially during sleep. Some sounds produced by similar means are voluntary, and designed by the animal as a means of communication or expression with its fellows or those of other species with which it may be associated, and therefore serving the purpose of language, as when a dog scratches its paws at the door of its master, to ask for admission. None of these noises, however, are vocal.

979. **Voice** is a faculty common to nearly all the superior classes of animals, and subject to greater variation, not only comparing species with species, but comparing individual with individual, than almost any other physical character. It is a sound produced by the propulsion of air through a cartilaginous apparatus established in that part of the throat between the hyoid bone, situate at the base of the tongue, and the uppermost ring of the trachea. The position of this apparatus in the throat is shown in fig. 366, p. 438, placed in front of the upper part of the œsophagus, and lying between the posterior cavity of the mouth, called the pharynx, and the top of the trachea.

980. This vocal apparatus is called the *larynx*. The hyoid bone to which it is attached, is placed at the upper part of the throat, immediately below the lower jaw, and is more or less moveable. To this bone the upper part of the larynx is attached by a membranous connection, which gives a certain freedom of motion to the parts connected with it.

981. **The Glottis.**—The part of the larynx which is the

immediate agent in the production of vocal sounds, consists of two membranous pieces stretched across the opening of the windpipe, the edges of which extend from the front backwards, being inclined slightly downwards. Each of these membranes covers something less than one-half of the entire passage of the windpipe. Between their edges a cleft or fissure is left, through which the air passes to and from the lungs. This apparatus is called the *glottis*.

Its form and structure may be illustrated by supposing two pieces of bladder or India-rubber to be stretched over the open end of a tube, as shown in fig. 446, so placed that each of them shall cover something less than half the opening, a fissure being left between them. If air be forced upwards through such a tube by means of bellows, a sound will be produced, provided the opening between the membranes be not too wide, and this sound may be made to imitate the voice of an animal. If expedients be adopted, which may easily be done, to vary the tension of the membrane, the sound will be more or less acute, according as the tension is increased or diminished.

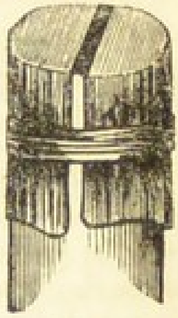


Fig. 446.

Now the glottis, as described above, being a fissure-like opening bounded by similar membranes, and the lungs having the power of propelling air through the fissure with more or less force, it follows that vocal sounds can be produced, provided that the appendages of the larynx connected with the membranes forming the glottis, are supplied with a provision by which the tension of the membranes and the breadth of the cleft or fissure between them can be varied within the necessary limits. When no sounds are desired to be produced, the fissure is left so open that the air in respiration passing through it, fails to put the elastic membranes which bound the fissure, into vibration, and consequently the aerial undulations which are the physical causes of sound, are not produced. But if by a voluntary action the apparatus of the larynx connected with the membranes forming the glottis, is capable of contracting the fissure, and giving the necessary tension to the membranes, then the conditions necessary to enable the expired air to throw the membranes into vibration being fulfilled, sound will be produced, the pitch of which will depend upon the tension of the membranes and the magnitude of the fissure, while the character of the sound will be influenced by a variety of other conditions depending on the form and magnitude of the passages through which the air thus put in vibration passes before it issues into the atmosphere,—that is, upon the form and magnitude of the pharynx and the other buccal and nasal passages.

982. From this brief statement it will be apparent that the larynx, combined with the lungs and trachea below it, and the cavities of the mouth and nose above it, forms in fact a sounding or musical apparatus, having a close analogy to certain reed instruments, such as the bassoon or hautboy, or certain organ-pipes. The lungs and trachea perform the part of the bellows and wind-

chest of an organ-pipe ; the larynx corresponds to the mouth-piece, or that part of the organ-pipe which gives the peculiar character to the sound ; and the mouth and nasal passages correspond to the tube of the instrument between the mouth-piece and the place from which the column of air thrown into vibration escapes into the atmosphere.

These points being explained, the structure of the larynx and the purposes which it is destined to attain will be easily comprehended.

983. **The Larynx** is formed of four principal cartilaginous pieces called, respectively, the thyroid, cricoid, and the two arytenoid.

The thyroid, so called from its shield-like form—θυρεὸς (thureos), *a shield*—is the largest of the pieces composing the larynx, and consists of two flat plates, the upper edges of which are curved into the form of the letter S. They are situated in front, at an acute angle along the median line, and form a prominent projection in the throat of a man, visible on the exterior, and vulgarly called *Adam's apple.* They are less perceptible in the female throat, being inclined at an obtuse or a much less acute angle. The upper edges of these alæ—or wings of the thyroid cartilage, as anatomists call them—have the form of the letter ∞ placed sideways. They are separated from the hyoid bones by a broad membrane, called from its connections the *thyro-hyoid membrane.*

The lower part of the thyroid cartilage is connected with the cricoid cartilage by another membrane called the *crico-thyroid membrane.* The cricoid cartilage itself lying below the thyroid, as shown in fig. 447, derives

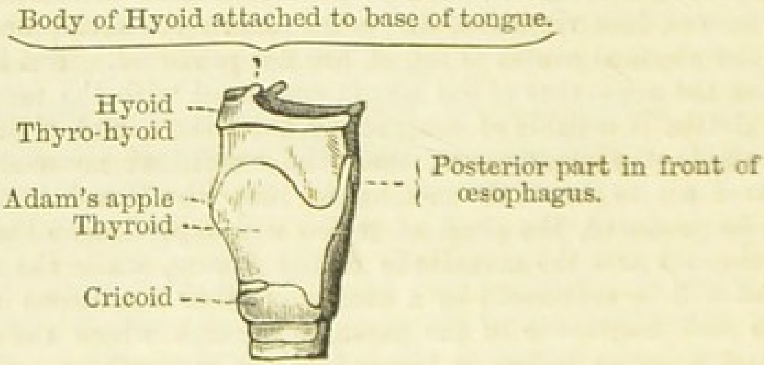


Fig. 447.

PROFILE OF THE LARYNX.

its name from its ring shape,—κρίκος (krikos), *a ring.* It completely surrounds the windpipe. Its lower border, being circular and horizontal, is connected with the uppermost ring of the trachea by a membrane. The upper border is curved, being much higher behind than before, the hinder part lying between the vertical edges of the alæ of the thyroid, so as to fill up the space surrounding that part of the larynx. The relative position and names of these several parts of the larynx, are shown in profile in fig. 447.

984. A vertical section of the larynx made in the median plane is shown in fig. 448, where the several parts are indicated. It will be seen that the

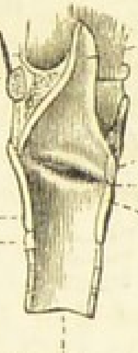


Fig. 448.

VERTICAL SECTION OF LARYNX BY THE MEDIAN PLANES.

inner surface of the hyoid bone inclines backwards, and is met by a sort of valve moveable on a hinge, called the *epiglottis*. In the figure this valve is represented as inclined against the hyoid bone so as to close the upper end of the larynx ; and in this position of the parts, all respiration would be stopped. This is a position, however, which the epiglottis never assumes, except during the act of deglutition. One of the uses, therefore, of the epiglottis is to close the larynx during deglutition, so as to prevent the food or drink from descending into the lungs instead of passing in its proper direction ; nevertheless, as every one has experienced, especially in drinking, it sometimes happens that the liquid, passing into the pharynx before the epiglottis has time to close the larynx, finds its way by mistake, as it were, into the larynx; or, as is vulgarly but quite correctly said, "goes the wrong way." If this were continued, suffocation would ensue ; but an involuntary spasmodic action instantly takes place, by which the liquid introduced is expelled in coughing, and if any remains it is soon evaporated.

985. Besides the two membranous cords forming the glottis properly so called, described above, there are two others at a small distance above them, much less considerably developed, and which, though not without some influence upon the vocal sound, have no part in its production. As the membranes of the glottis have received the name of the *inferior*, or *true vocal cords*, the latter have been called the *superior*, or *false vocal cords*. In the vertical section of the larynx shown in fig. 448, both of these cords are represented inclined slightly from the front backwards, and including between them a space indicated by dark shading. This space is called the *ventricle of the glottis*.

986. The two arytenoid cartilages are immediately connected with the true vocal cords, and also by proper muscles, as well with the thyroid as the cricoid cartilages, and, as will presently be explained, form an important part of the mechanism by which the tension and separation of the vocal cords are governed.

A front view of the larynx is shown in fig. 449, the several parts being indicated as before; and the form of its entire surface, produced by a section made by a vertical plane through the centre of the larynx at right angles to the medial plane, is indicated by the dotted lines.

In fig. 450 a front view of the thyroid cartilage is shown on a larger scale; where 1 is the summit of the vertical ridge, forming what is called

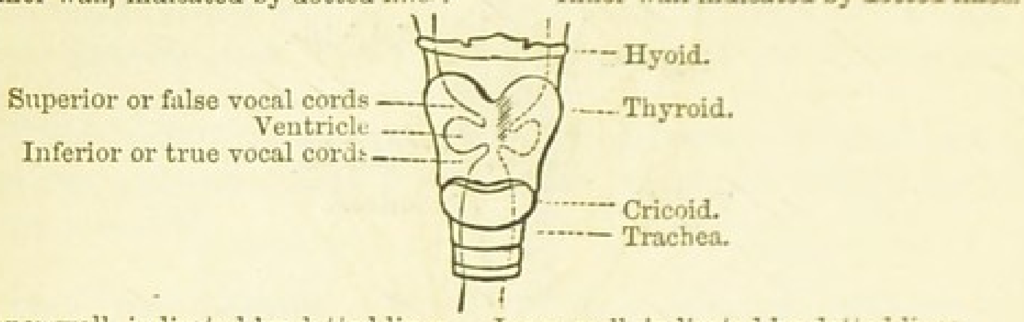


Fig. 449.

LARYNX VIEWED FROM THE FRONT.

Adam's apple; 2, the right ala, or wing; and 3 and 4, a posterior projection called the cornu, or horn. In fig. 451 is shown a front view of the cricoid cartilage; where it will be seen that the front part, 6, is very

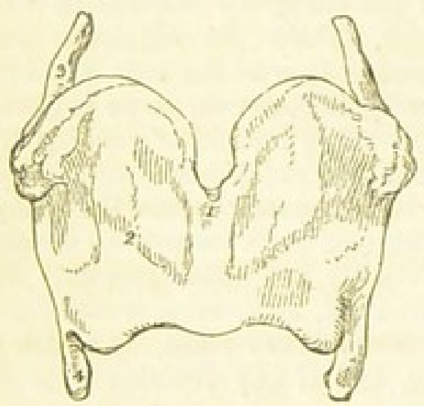


Fig. 450.

THYROID CARTILAGE. FRONT VIEW.

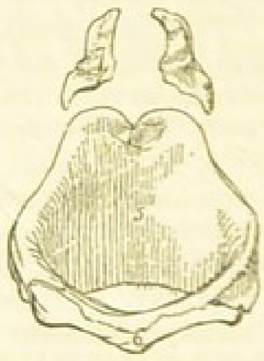


Fig. 451.

CRICOID CARTILAGE. FRONT VIEW.

narrow, while the posterior part rises so as to fill the space between the posterior edges of the thyroid. The forms of two arytenoid cartilages are shown at 7; but these will presently be more fully described.

In fig. 452 is shown a view of the glottis and the parts immediately connected with it, as it would be seen if looked at downwards, in a line directed along the axis of the windpipe.

The relative position and structure of the parts will be rendered more clear by figs. 453 and 454.

In fig. 453 is presented a profile view of the thyroid and cricoid cartilages, with part of the trachea. In fig. 454 is a posterior view of the larynx and part of the trachea, dissected to display the muscles.

987. It appears from experiments made with the artificial larynx, such as that described in 981, and on the natural larynx dissected; from the dead subject as well as observations

made on cases of throat-wounds, accidentally or self-inflicted,

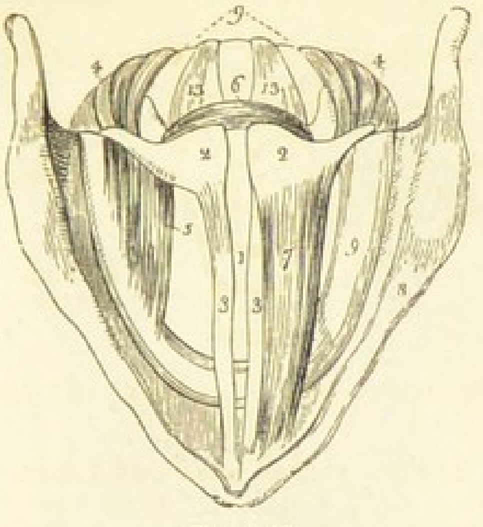


Fig. 452.

BIRD'S-EYE VIEW OF THE INTERIOR OF THE LARYNX AND OF THE SURROUNDING PARTS (Willis).

1. Opening of the glottis.
2, 2. Arytenoid cartilages.
3, 3. Vocal cords.
4, 4. Muscles connecting the posterior parts of the cricoid with those of the arytenoid cartilages, called the posterior crico-arytenoid muscles.
5. Muscles connecting the anterior parts of the right arytenoid with the corresponding parts of the cricoid. Similar muscles connect the left arytenoid with the left part of the cricoid, which are removed in the figure. These are called the lateral crico-arytenoid muscles.
6. Muscle connecting the two posterior parts of the arytenoids, called the arytenoid muscle.
7. Muscle connecting the left arytenoid with the thyroid. A similar muscle in the right arytenoid is omitted in the figure. These are called the thyro-arytenoid muscles.
8. Upper border of the thyroid cartilage, seen by projection, being, however, at a much higher level than the vocal cords.
9, 9. Upper border and posterior part of the cricoid cartilage.
13, 13. Ligament connecting the posterior parts of the arytenoid with those of the cricoid, called the posterior crico-arytenoid ligament.

on the human subject, and inflicted for the purposes of science on inferior animals; that the glottis is the instrument—and the sole instrument—of voice. The trachea and inferior parts of the respiratory apparatus have no other share in the production of sound than the bellows, air-chest, or air-conduits, have in the production of the notes of an organ. The parts of the larynx, the buccal and the nasal cavities above and before the glottis, have a certain influence in modifying the tone and character of the vocal sounds, but have no share whatever either in their production or in determining their pitch. Müller showed that, with an artificial larynx constructed in the manner described in 981, vocal sounds could be produced, corresponding with those of the human voice, and that

their character could be varied by placing above the artificial

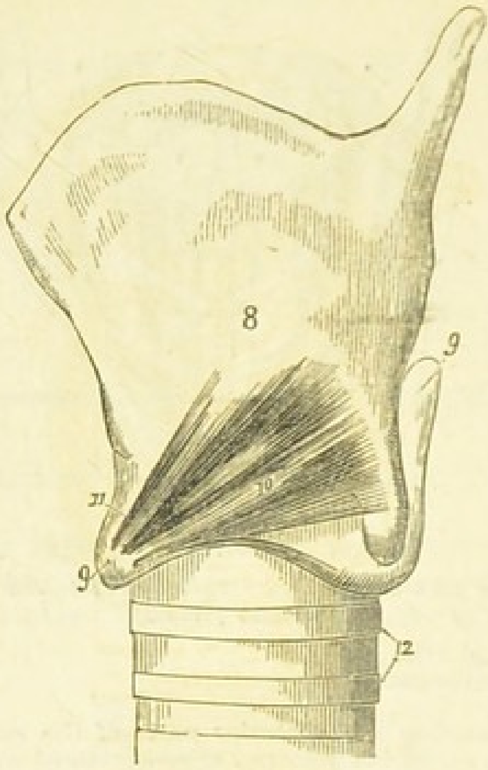


Fig. 453.

SIDE VIEW OF THE LARYNX (Willis).

8. Thyroid.
9, 9. Cricoid.
10. Crico-thyroid muscle.
11. Crico-thyroid membrane.
12. Upper rings of trachea.

larynx tubes or cavities variously formed. It is, however, with the natural larynx dissected from the dead subject that the most conclusive and satisfactory experiments have been made.

988. These experiments, and the manner of performing them, are illustrated in the diagrams (fig. 455 and fig. 456), the former representing the arrangement by which the sonorous effects of the larynx alone, separated by the section from the parts above and below it, and the latter that by which the vocal effects of the organ with all its accessories are illustrated.*

Fig. 455 represents the larynx, separated from the cartilaginous parts above and below it, fixed by its cricoid cartilage against an upright pillar. The scale *c*, suspended to the projecting part (*l*) of the thyroid cartilage, is loaded with a weight which can be varied at pleasure, and which, playing the part of the crico-thyroid muscles, causes the thyroid cartilage to turn

* These two diagrams have been copied by permission from Béclard.—*Traité de Physiologie Humaine.*

on its junction with the cricoid as upon a hinge, and thus to vary the tension of the vocal cords according to the varying weight put into the

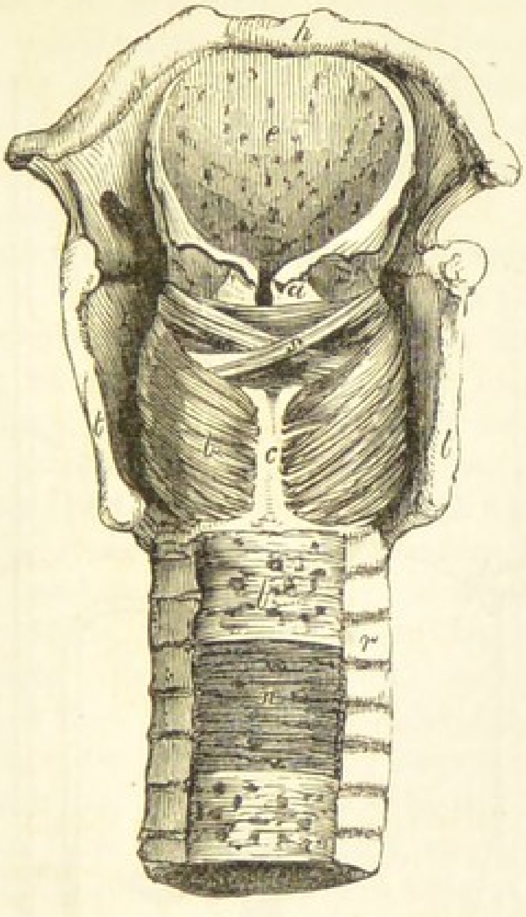


Fig. 454.
TRACHEA DISSECTED (Quain).

a. Right arytenoid cartilage.
t, t. Posterior margins of thyroid.
c. Back of cricoid.
h. Hyoid bone.
e. Epiglottis.
b. Left posterior crico-arytenoid muscle.
s. Arytenoid muscle.
l. Fibrous membrane at back of trachea, with glands lying on it.
n. Muscular fibres of trachea.
r. Cartilaginous rings of trachea.

scale *c.* A little apparatus, *a*, fixed to the pillar above the larynx, is so adapted as to be capable of varying the opening of the glottis within given limits by means of weights placed in the scales *b b*. Air is forced through the glottis by applying a bellows to the tube *d*, which in this case represents the trachea, while the bellows represents the lungs.

Connected with the tube *d* is a siphon mercurial gauge *m*, indicating the pressure of the air which acts upon the glottis. In the experiments thus made, it was found that the larynx detached from the body could produce all the tones corresponding to the register of the human voice,—that is, from 2 to 2½ octaves. These tones were produced after all parts of the larynx above, and before the inferior, or true vocal cords, were removed. With every addition of weight placed in the dish *c*, the pitch of the note produced was raised, and with every diminution of weight it was lowered. When the fissure of the glottis was left in the state in which it remained after death, the scales *b* and their weights being detached, a vocal sound

was still produced; but it was a hoarse and low one, showing that the opening of the glottis was still sufficiently contracted to produce a sound, though one very low in the scale.

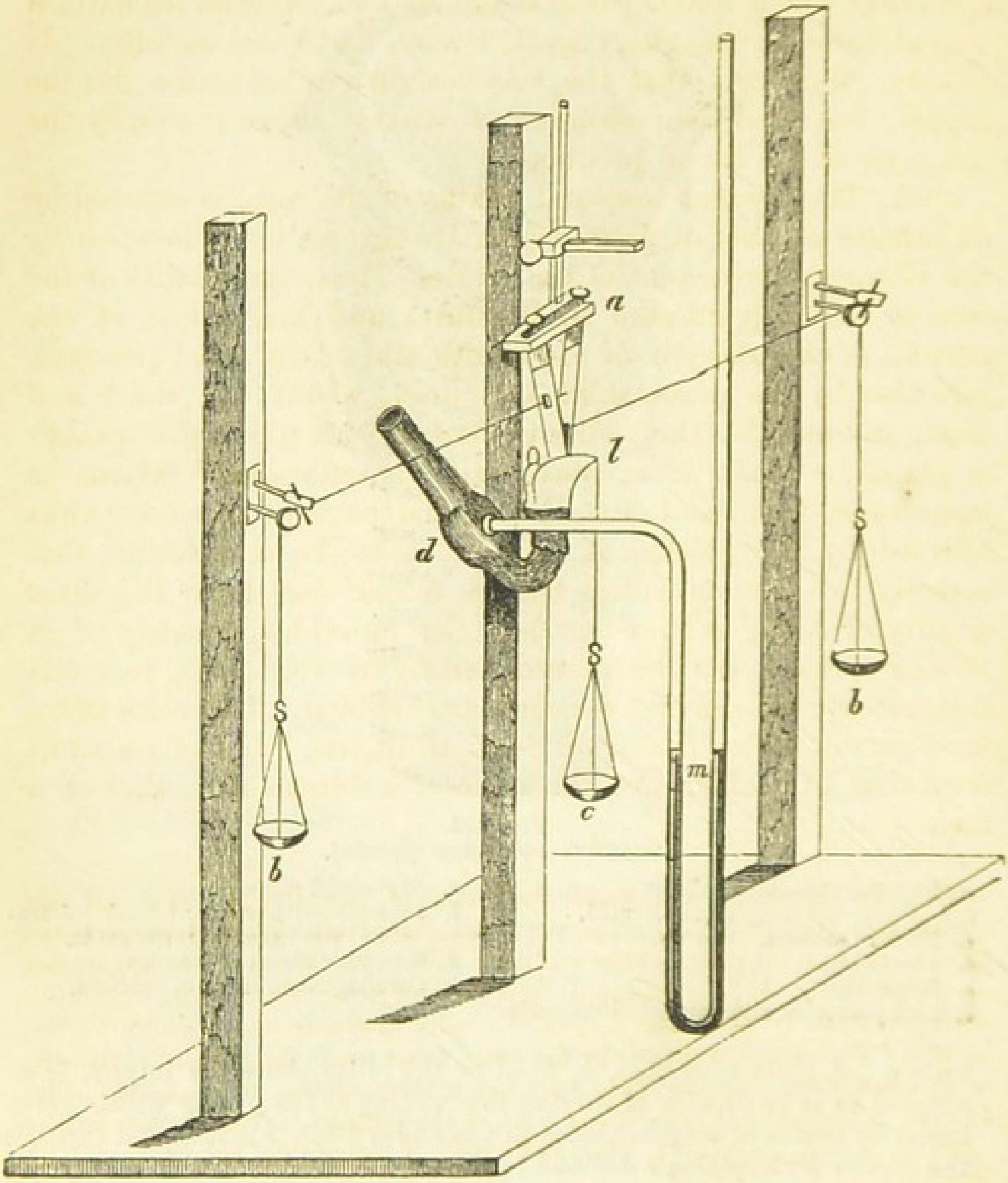


Fig. 455.

989. That the glottis and vocal cords are the true and only instruments of voice is proved by two classes of experiments. If an incision be made in the trachea at any point below the glottis, however near to it, so that the air expired shall escape without passing through the glottis, no sound can be produced.

If, on the other hand, an incision be made above the glottis,

no matter how near to it, so that the air expired shall escape through it without passing through any of the superior parts, a vocal sound will be produced, differing in its tone only from that which would ensue if the air had followed its natural course through the pharyngeal, buccal, and nasal cavities. It follows, therefore, that the sole instrument of voice is the glottis, but that the passages and cavities above it modify the character of the sound produced.

990. The peculiar tone and quality of the voice is affected by an infinite number of parts, which are thrown into vibration by the vibratory movement of the glottis. Thus, the quality of the tone is not only affected by the form and magnitude of the cavities of the pharynx of the mouth and of the nasal passages, but also by the parts, solid and fluid, about the chest and head, and even by the bodies in contact with which the speaker is placed. When it is considered, therefore, how various in magnitude, form, and material are the parts of the body thus affected by the glottis, it will cease to be wonderful that scarcely two human voices can be found that have the same quality of tone, so that not only the individual identity of an unseen speaker can be determined by his voice, but, to a certain extent, the age and sex are betrayed by it. The voice of an aged person differs from that of an adult, the voice of an adult from that of a child, and the voice of a woman from that of a man.

991. To illustrate the vocal functions of the larynx with all its appendages, the head and other parts detached from the dead subject are fixed to an upright piece, as shown in fig. 456. In this case, the apparatus *a*, shown in fig. 455, is replaced by a sort of compressor (*a a*, fig. 456), acting externally upon the larynx, so as to graduate the opening of the glottis. The weights placed in the scale C act upon the thyroid cartilage, as in the former case, so as to vary the tension of the vocal cords. The tube *d*, connected with the lower part of the trachea, serves for the introduction of air, a bellows connected with it supplying the place of the lungs.

In experimenting in this way it is not possible, as in the former case, to determine with precision the varying magnitude of the opening of the glottis; but, on the other hand, it demonstrates in a striking manner the influence exercised by all the superjacent parts in swelling and giving intensity to the voice, and imparting to it the peculiar tone, quality, or timbre, which characterises the living voice.

992. In speaking, the pitch of the voice is subject to but little variation, being generally limited to half an octave. In singing, however, the register, as it is called, is much more

extensive, its limits varying with different individuals, and still more with different ages and sexes. The musical characters of

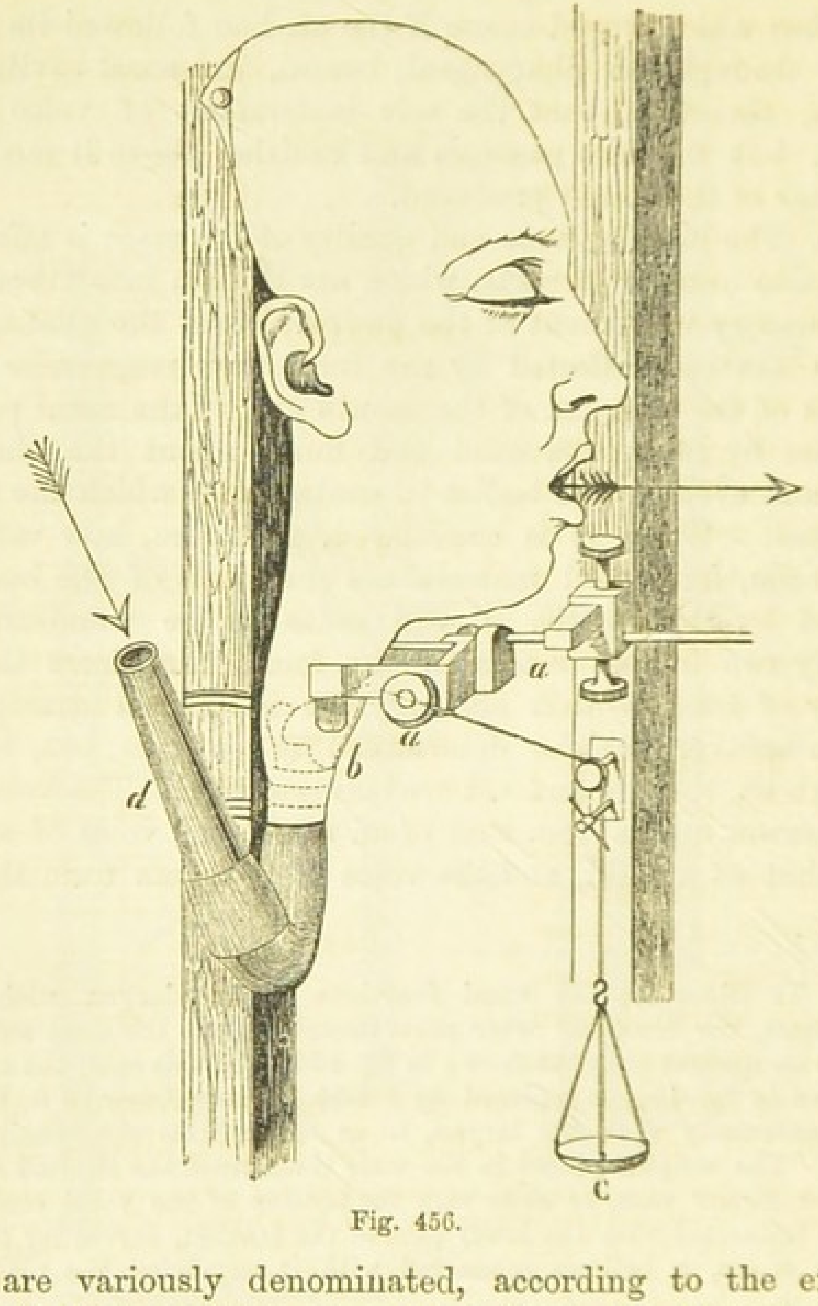


Fig. 456.

voices are variously denominated, according to the extreme limits of their register, proceeding from the highest to the lowest in the scale, as follows: *soprano*, *contralto*, *tenor*, *barytone*, and *basso*. The soprano and contralto are voices found only in females or in children. Boys' voices—before the age of puberty—are generally contraltos. The tenor, barytone, and basso, are men's voices. Since every individual organ differs from another, no exact limits can be assigned to these several classes of organs. One soprano will have a higher or lower register than another, and the like may be said of the other classes of

voices. The mean limits, however, for each of these classes, is indicated as follows: the numbers annexed to them being the number of double vibrations of the glottis which are produced in a second of time. The production of each note is ascertained by the experimental researches of Cagnard de la Tour, Savart, and others.

It appears, therefore, that the extreme limits of the vibratory power of the female glottis of a soprano singer, is 1056 and 264 double vibrations per second.*

993. **Speech** consists of articulated vocal sounds. Voice is common to all mammifers, but speech is the peculiar privilege of man. Although mammifers in general possess the organs of articulation, consisting of the pharynx, the nasal cavities, the veil of the palate, the tongue, cheeks, teeth, and

* A single vibration of a pendulum consists of one movement from left to right, and a double vibration of two movements; one from right to left, and the other from left to right. Since the lips of the glottis in vibration move alternately up and down, a double vibration consists of two such motions, one from the extreme limit upwards to the extreme limit downwards, and the other from the extreme limit downwards to the extreme limit upwards. The pitch of the note depends only on the number of vibrations per second. Its intensity or loudness, other things being the same, depends upon the space through which the vibration takes place. In calculating the numbers of vibrations in the above table the pitch of A in the treble is assumed to correspond to 440 double vibrations. The pitch of this note varies within narrow limits in different schools and orchestras in Paris and Berlin, between 424·14 and 437·32. It appears from some experiments recently made by Mr. Donovan of Dublin, that the present concert pitch of the principal London orchestras is nearly 450. The superior limits of the mean register of the soprano and tenor given above are perhaps a little too high, though many voices of this class have arisen above them. The classification of voices, however, is somewhat arbitrary, and is determined by the best and most effective parts of the register as often as by its extreme limits (see Handbook Nat. Phil., Acoustics).

lips, they are nevertheless incapable, in general, of producing articulate sounds, and still more of using these for the expression of thoughts or feelings. Individuals affected with idiotcy from their birth are incapable of producing any other vocal sounds than inarticulate cries, although supplied with all the internal instruments of articulation. Persons deaf and dumb are in the same situation, though from a different cause; the one being incapable of imitation, and the other being deprived of the sense of hearing the sounds to be imitated.

994. **Mammifers** are capable of producing vocal sounds, which vary with different classes. Thus, the horse neighs, the dog barks, the cat mews, the ass brays, the cow lows, the pig grunts, the lion roars, and so on.

These various modifications of voice depend on the peculiar structure of the larynx, but much more upon the buccal and nasal cavities.

995. **The Horse** has a glottis formed of simple vocal cords, considerably developed and surmounted on each side by ventricles having a wide entrance. The vocal glottis scarcely measures half the glottidal fissure, and the interarytenoid glottis is more developed than in man. The neighing is produced by a succession of interrupted expiratory movements. The tension of the vocal cords gradually decreases during the continuance of the expiration; and, consequently, the first sounds of the neighing are more acute than the last.

996. **The Ass** has a larynx which, like that of the horse, is supplied with only two vocal cords. The ventricles are large, but the entrance to them much smaller. The voice of the ass has a peculiar character, commencing by an inspiration, which produces an acute sound, and terminating by an expiration, producing one more grave.

997. **The Ox** has a larynx differing considerably from those of the solidungular classes. The glottis is short, and the vocal cords scarcely detached upon the surface of the larynx. There are no ventricles. The voice of this animal is much more imperfect than that of the horse, consisting of a moaning sound, or lowing, having a very low pitch and very little varied.

998. **The Dog** has the inferior vocal cords well detached

and thin upon their edges. The superior cords are scarcely perceptible. The ventricles are large, but the entrance to them narrow. The voice of the animal is subject to much variation and capable of different modes of expression. Sometimes it barks, sometimes growls, snarls, and often utters a sort of neighing expressive of pleasure.

999. **The Cat** is distinguished from other mammifers, as well as from man, by the almost equal development of the inferior and superior vocal cords. The mewing begins by a very acute sound, which becomes more and more grave as the mouth, first open, is gradually closed. The voice of the cat, like that of the dog, is endowed with a certain extent of register. Its power of producing sounds in the higher parts of the scale is especially remarkable at certain sexual periods, when its voice bears a close resemblance to that of an infant. It has not been certainly ascertained what effect the superior vocal cords of the cat produce. It is probable, however, that in this, as in other mammifers, the principal vocal organ is the inferior vocal cords.

1000. **The Pig** has a larynx characterised by the anterior insertion of the inferior vocal cords upon the tracheal edge of the thyroid cartilage. The arytenoid cartilages united above the superior vocal cords are merely rudimentary ; the ventricles, which are deep, communicate with the interior of the larynx only by a narrow fissure. The animal has two sorts of cries ; the one low, called grunting, and the other more acute, when it is goaded or provoked.

Other Animals are endowed with voice, but rarely use it. Such are the stag, the rabbit, the hare, and so on. Animals which howl and are heard at night at great distances, have generally large laryngeal ventricles. Certain apes of the South American continent are especially remarkable in this respect. The howling apes which prevail in large troops in Guiana, have hyoid bones, terminated on each side by a bony enlargement lodged in the process of the lower jaw. This enlargement, which is hollow, communicates with the laryngeal ventricles prolonged below the epiglottis and thyro-hyoid membrane, and gives to their voice a peculiar character.

1001. **Birds** have two larynxes, a superior and inferior. The

superior, which corresponds to the larynx of mammifers, and which is placed at the superior opening of the respiratory passages in the pharynx, can only be regarded as an accessary of the voice. The thyroid, cricoid, and arytenoid cartilages are severally rudimentary. The opening by which the thyroid cartilage leads into the pharynx can be increased or diminished by muscles which are grouped round it; but it cannot properly be called the glottis. The true larynx of birds is the inferior larynx, placed at the inferior part of the trachea, where it bifurcates. This larynx consists of several parts: an enlargement, the sides of which are partly bony and partly membranous, corresponds to the inferior part of the trachea. This enlargement is called the *drum*, and is divided at the point of junction of the bronchiæ by a bony transverse piece surmounted by a thin membrane of semilunar form. At the point where the two superior orifices of the bronchial tubes communicate with the drum, they are bordered each by two lips, or vocal cords, one of which is generally more developed than the other. There are besides, between the different rings of the inferior larynx, muscles more or less numerous, the function of which is to stretch the different membranous folds which they sustain. These muscles are merely rudimentary in gallinaceous birds. There is one pair of them in the eagle, vulture, buzzard, and the cuckoo, three in the parrot, and five in singing birds, such as the nightingale, the lark, the canary, &c. These muscles have all a common insertion in the trachea, being fixed at the

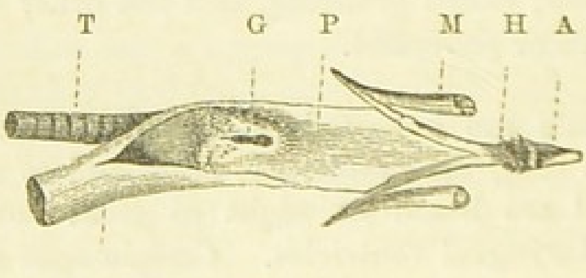


Fig. 457.

TONGUE AND GLOTTIS OF A GRANIVOROUS BIRD.

A. The Tongue.
H. Hyoid Bones.
M. Muscles of the Hyoid.
P. Pharynx.
G. Glottis.
T. Trachea.
O. Gullet.

other end to the first rings of the bronchial tube. Independently of these, there are other muscles charged with the function of lowering the trachea, and thus diminishing the

length of the vocal tube, the length of which can also be modified by the action of the levator muscles of the hyoid, which, as in mammifers, are connected with the thyroid cartilage. The levators and depressors of the trachea also have some influence upon the tension of the lips of the glottis of the inferior larynx, the elevation and depression increasing and relaxing such tension.

The details of these organs will be more clearly understood by reference to figs. 457, 458, and 459.

That the inferior larynx is the true vocal organ of birds, is proved by the fact that the voice is not sensibly modified when an incision is made in the trachea below the superior larynx and above the inferior, while, on the other hand, very varied sounds can be produced with the inferior larynx after the superior has been entirely removed.

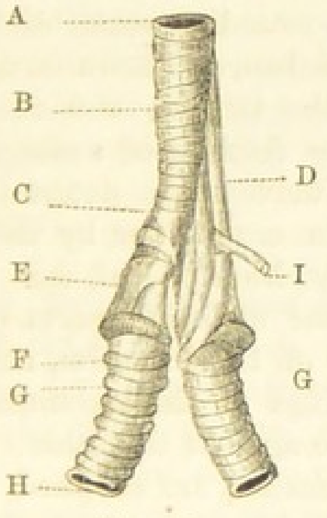


Fig. 458.

INFERIOR LARYNX OF A CROW.

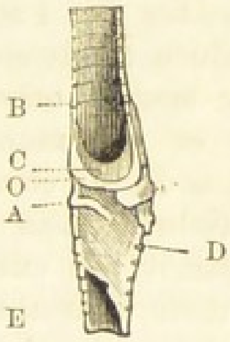


Fig. 459.

VERTICAL SECTION OF THE LARYNX.

In fig. 458 is represented the larynx of a crow. A B. The trachea. C. The drum formed by the inferior extremity of the trachea. E. The middle bone of the trachea. F. The first ring of the bronchia separated from the third bone of the larynx by a membranous space. G. the bronchia. D. the proper muscles of the larynx, which have been removed on the opposite side. I. The depressor muscle of the trachea.

A vertical section of the larynx is shown in fig. 459. B. The inferior portion of the trachea cut through the middle. C. The semilunar membrane situated above the point of union of the two glottises, and fixed to the bony transverse piece, O. A. The rim or flange formed by the internal lip of the glottis of the right side. D. The internal face of the right bronchia formed by a tympanic membrane. E. A part of the cavity of the right bronchia laid open by the section of a part of that membrane.

The voice of birds is produced like that of mammifers, by the vibration of the lips of the glottis. The function of the semilunar membrane, which surmounts the bony piece of the drum, has not been satisfactorily determined. It is probable, however, that it enters into vibration when vocal sounds are produced. The drum itself is the organ by which the intensity of the sound is increased, and is analogous to the laryngeal ventricles of mammifers. The varying length of the vocal tube determined by the play

of the depressor and levator muscles of the trachea, have much more extent in birds than in mammifers, and no doubt produce important modifications in the modulation of the voice.

1002. **Reptiles** have sometimes a true voice, as is evident in the case of frogs, toads, and other amphibia. The cavity of the larynx presents upon the sides membranous folds, which, parting from the base of the arytenoid cartilages, may properly be called vocal cords. It is by these that the noise called croaking is produced. Bull frogs also exhibit on each side of the neck, under the ear, an apparatus for increasing the intensity of sound, consisting of an elastic membranous pocket, which opens into the mouth upon the side of the tongue, and dilates when the animal croaks.

1003. **Insects** in general produce sounds remarkable by their acuteness. Since they breathe by trachea, as shown in fig. 363, they have no organ analogous to the larynx, and the noises they produce result either from the friction of some parts of the body against others, or from movements determined by the play of the muscle on certain organs, or by the larger spiracles, as in the common house-fly, humble-bee, &c. Some insects produce noise by rubbing the dentated parts of their thighs against the external border of their elytræ, others by rubbing their elytræ against the rings of the abdomen, or by rubbing the rings of the thorax one against the other. Other insects, such as grasshoppers and cicadæ, are supplied on the sides of their bodies with a little dry membrane extended upon a horny frame, to which they impart oscillation by the aid of a muscle which acts upon it in the same manner as the muscles of the chain of tympanic bones act on the ear—that is to say, by a rapid alternation of tension and relaxation. Other insects produce noises which do not depend at all upon the play of their organs, but upon the action of some of these organs on the bodies around them; such, for example, are various insects which gnaw wood, and which strike either with their mandibles or with the hard extremity of their abdomen.*

* Béclard, Physiologie Humaine, p. 600.

CHAPTER XVIII.

DEVELOPMENT.—MATURITY.—DECLINE.—DEATH.

1004. **The Egg.**—The origin of life is wrapped in mystery. Nevertheless, the phenomenon of vitality has been traced back to points that cannot be far removed from the main-spring which owes its tension to the immediate will of the Creator. Animals holding the lowest place in the scale of organisation commence their visible vitality in phenomena having a close relation to those of vegetation. Such modes of reproduction, however, are strictly limited to the lowest forms of organic life, all animals of superior organism originating in an *egg* or *ovum*.

1005. **Oviparous and Viviparous.**—In some the egg is hatched *before*, in others *after* it is laid. Although, strictly speaking, all such are therefore *oviparous*, that term has been limited to those classes in which incubation succeeds oviposition. Those classes whose eggs are hatched within the maternal body are called *viviparous*.

With some oviparous animals the eggs after being laid become objects of the most tender solicitude on the part of the mother, who not only hatches them by the warmth of her own body, but tends the young after breaking the shell till they become capable of tending themselves. With others, certain insects for example, the eggs are deposited in places where they can be protected from the vicissitudes of weather and the attacks of natural enemies, and where the young on issuing from them may find a provision of suitable nourishment, and a medium corresponding to the character and functions which mark the first period of their existence. These precautions being taken, the mother abandons the egg, and often dies before the young come to life.

1006. **Structure of the Egg.**—Nothing can be more

interesting and instructive than to trace the organic development from the egg to maturity and final dissolution. To follow such an exposition, however much it may be simplified and divested of technicalities, it will, nevertheless, be necessary to be familiar with certain terms which express the forms of the parts of the egg and the succession of changes incidental to them.

1007. **The Ovary** is the part of the maternal body in which the egg is evolved. That of a mammifer is represented in fig. 460.

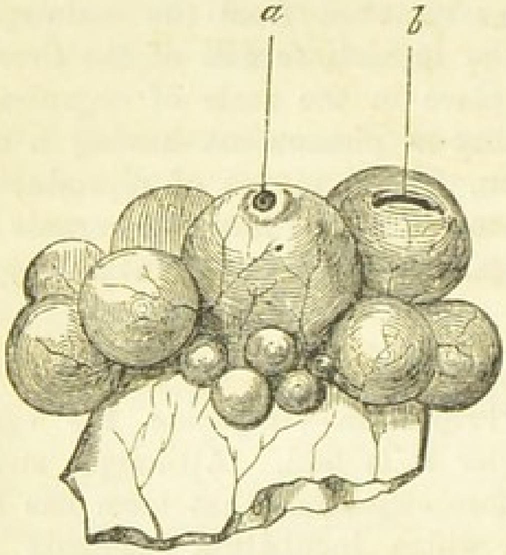


Fig. 460.

OVARY OF A MAMMIFER—THE PIG (Pouchet).

1008. **Graafian Follicles**, or vesicles, is the name given to the envelopes in which the eggs are enclosed in the ovary of mammifers. The corresponding envelopes in the ovary of birds are called *ovicapsules*, or *ovisacs*. When the development of the egg has attained a certain limit it bursts the envelope, and being expelled, is received into a tube called the *Fallopian tube*, from which it passes to another part of the organism, where it remains until the moment of transition from embryonic to natural life.

Like most other organs, the ovaries, and their appendages, the Fallopian tubes, exist in pairs, symmetrically placed at either side of the median plane.

In fig. 460 the Graafian follicles are shown in different stages of development. A follicle from which the egg has just escaped is shown at *b*, the opening having the form of a cleft, and another at *a*, in which it is round. The follicle is sometimes rent at the edges.

1009. The follicle is filled with a transparent yellowish liquid, analogous to the serum of the blood, holding in suspension a multitude of elementary granulations. Against the inner surface of the surrounding membrane, a stratum of matter of cellular structure is applied, which forms a sort of epithelial coating upon it. This is called the *granular membrane*. The *ovum* is much smaller than the follicle, and lies against its inner wall surrounded by a mass of cellular matter, called the *discus proligerus*.

A theoretical section of one of the Graafian follicles in an advanced state of development is shown in figs. 461, 462.

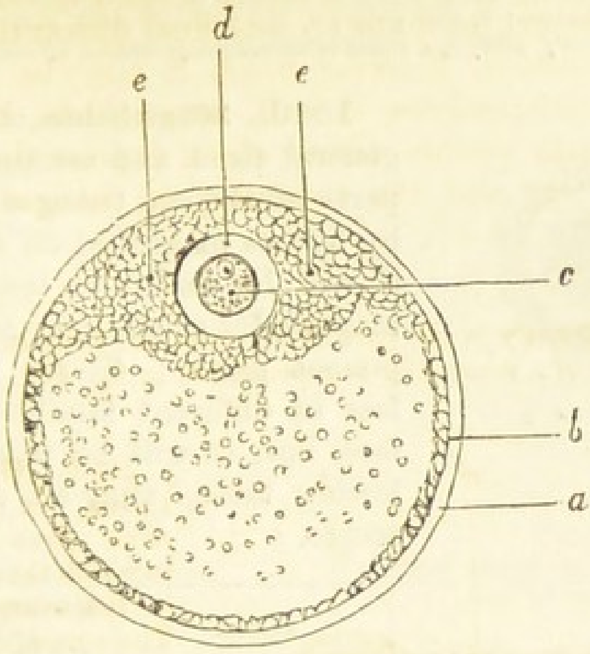


Fig. 461.

SECTION OF GRAAFIAN FOLLICLE AND OVUM (Beclard).

a, is the external coating of the follicle; *b*, the granular membrane within it; *c*, the ovum; *d*, the vitelline membrane, called also the zona pellucida; *e*, *e*, the discus proligerus.

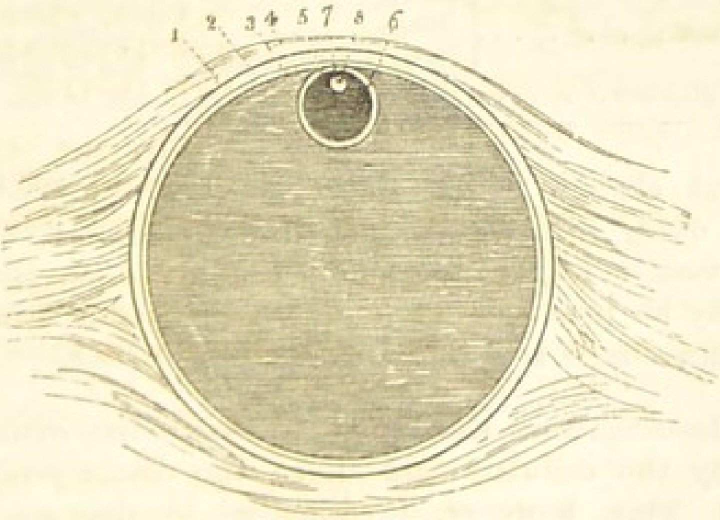


Fig. 462.

SECTION OF THE GRAAFIAN FOLLICLE AND OVUM OF MAMMIFER (Müller).

1, is the stroma or tissue of the ovary; 2 and 3, the external and internal tunics of the follicle; 4, the cavity of the follicle; 5, the vitelline membrane, being the tunic of the ovum; 6, the yolk; 7, the germinal vesicle; 8, the germinal spot.

In fig. 463, the ovum of the sow is shown, in which 1, is the germinal spot; 2, the germinal vesicle; 3, the yolk; 4, the pellucid zone, surrounding the yolk, 5, the granular coat; and, 6, a mass of adherent granules or cells.

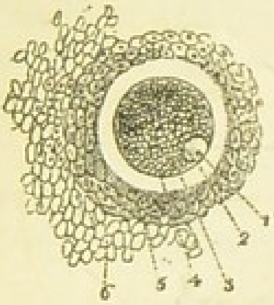


Fig. 463.

1010. **Magnitude of Egg.** — The general form and arrangement of the parts of the egg being thus explained by figures magnified on a great scale, it will be useful to indicate the real magnitudes of the eggs and their component parts. These vary more or less in different families of mammifers, but, as will be seen by the following table,* they are always microscopic.

	Animal.	Measurement in parts of a Paris inch.	Observer.
Diameter of mature ovum	Man	$\frac{1}{240}$ to $\frac{1}{120}$	Bischoff.
	Rabbit	$\frac{1}{150}$	Ditto.
	Bitch	$\frac{1}{147}$ to $\frac{1}{142}$	Ditto.
Thickness of zona pellucida	Man	$\frac{1}{2500}$	Ditto.
	Rabbit	$\frac{1}{2500}$ to $\frac{1}{1250}$	Ditto.
	Bitch	$\frac{1}{1600}$ to $\frac{1}{1250}$	Ditto.
Germinal vesicle	Rabbit, Bitch	$\frac{1}{100}$	Ditto.
Germinal spot	Bitch	$\frac{1}{2500}$	Ditto.
	Mammalia generally	$\frac{1}{3600}$ to $\frac{1}{2400}$	Wagner.
Large yolk globules	Ditto	$\frac{1}{6000}$ to $\frac{1}{4000}$	Henle.

The first change which the ovum sustains after passing from the ovary into the oviduct is the disappearance of the germinal vesicle which surrounds the germinal spot. This change may be produced even before the ovum escapes from the Graafian vesicle and enters the Fallopian tube.

1011. Issuing from the Graafian vesicle the ovum is surrounded by the cellular mass called the *discus proligerus* (*c*, fig. 461). This, however, is dissolved by degrees, and soon disappears. In passing through the Fallopian tube, it is surrounded by an albuminous coating, which has but little thickness.

1012. **Segmentation of the Yolk.**—Embryonic development

* Supplement to Müller's Physiology by Drs. Baly and Kirkes, p. 35.

is preceded by the remarkable phenomenon known as the *segmentation* of the yolk, which takes place in the following manner.

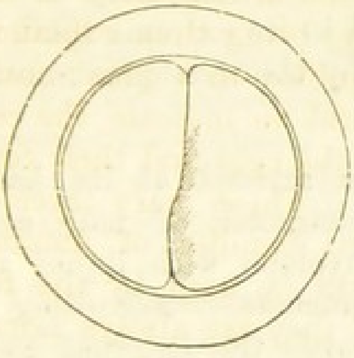


Fig. 464.
FIRST STAGE OF SEGMENTATION OF EGG OF MAMMIFER.

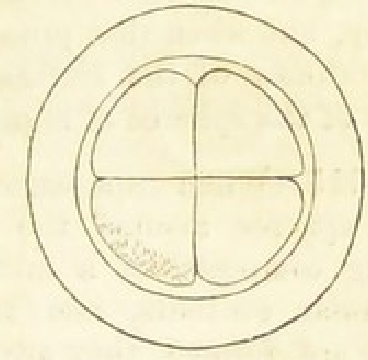


Fig. 465.
SECOND STAGE OF SEGMENTATION OF EGG OF MAMMIFER.

In the midst of the yolk appears a nucleus having a nucleolus. This seems to exert a central attraction upon the surrounding mass, and causes the yolk to contract, so as to leave a clear space between it and the vitelline membrane. The sphere thus formed is the first sphere of segmentation.

The central nucleus now divides into two, which take separate positions in the centre of each hemisphere of the yolk, and which, exercising a central attraction on the surrounding matter, cause the first sphere of segmentation to resolve itself into two, as shown in fig. 464.

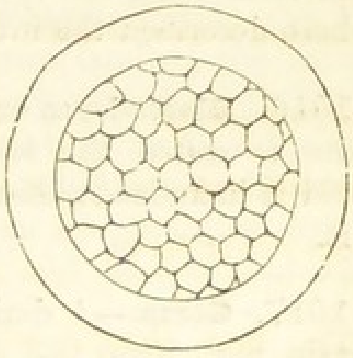


Fig. 466.
COMPLETE SEGMENTATION OF EGG OF MAMMIFER.

The two nuclei thus produced are then again subdivided each into two, which, operating by like central attraction, resolve the yolk into four, as shown in fig. 465.

In the same manner, the resolution of each nucleus thus successively produced into two, causes the yolk to be successively divided into 8, 16, 32, &c., parts. As the division is thus continued, the spheres of segmentation are multiplied in number, and proportionally diminished in magnitude.

1013. The phenomenon here described is called *complete segmentation*, inasmuch as it affects the entire mass of the yolk. In some animals, however, among which birds are included, a part of the yolk only, called the *cicatricula*, is subject to this segmentation, but in other respects the phenomena are the same. In the comparison of the embryonic phenomena of birds and mammifers, it must therefore be remembered that the cica-

tricula of the bird's egg is the analogue of the entire yolk of the mammifers.

1014. By the process of successive segmentation the surface of the egg assumes the external appearance of a blackberry or mulberry, but when that process is carried to its extreme limit the smoothness of the surface is restored by the indefinite minuteness of the spheres of segmentation.

1015. When the segmentation has arrived at its limit, the spheres assume the form and character of true cells, being composed of a membranous envelope with liquid and granular contents, and an internal nucleus. According as they are formed, they are pushed towards the external membrane of the egg by the pressure of the albuminous liquid contained within it. Their forms are changed by the pressure to which they are subject, and finally this pressure reduces the masses of cellular matter to a membrane surrounding the yolk lying against the vitelline membrane, so that the egg is enclosed in two membranes, one within the other, the vitelline membrane being the external, and the new membrane produced as here described the internal.

1016. **Blastoderm or Germinal Membrane.**—This new membrane is called the *blastoderm* or *germinal membrane*. The liquid it includes is albuminous, with granular particles floating in it.

1017. **Germ.**—A dark and opaque spot now appears at a certain part upon this germinal membrane, which proves to be the first vestige of the future embryo. This spot is called accordingly the *embryonic* or *germinal spot.*

While these phenomena are being developed, the egg passes through the Fallopian tube, and its dimensions are gradually increased. Its diameter, which, on leaving the ovary, is scarcely more than the 200th of an inch, is increased on leaving the Fallopian tube to the 50th of an inch.

A rapid series of changes takes place in the egg after it leaves the Fallopian tube. The embryonic spot, at first circular, is elongated, and becomes elliptical. A bright line appears along its centre, in the midst of which is traced indications of the spinal marrow. Meanwhile, the germinal membrane, which was at first simple, is resolved into two laminæ, one within the other, the external being called the serous or *cutaneous*, and

the internal the *mucous* lamina. The former supplies the materials, out of which the tegumentary envelope, or external skin of the future animal will be formed; and the latter the mucous membrane, or skin which lines its internal cavities.

Some physiologists have maintained that the external lamina supplies the matter out of which the bones, muscles, and organs of sense are formed. According to Reichert, however, whose account we follow, the superficial lamina is limited to the formation of the skin.

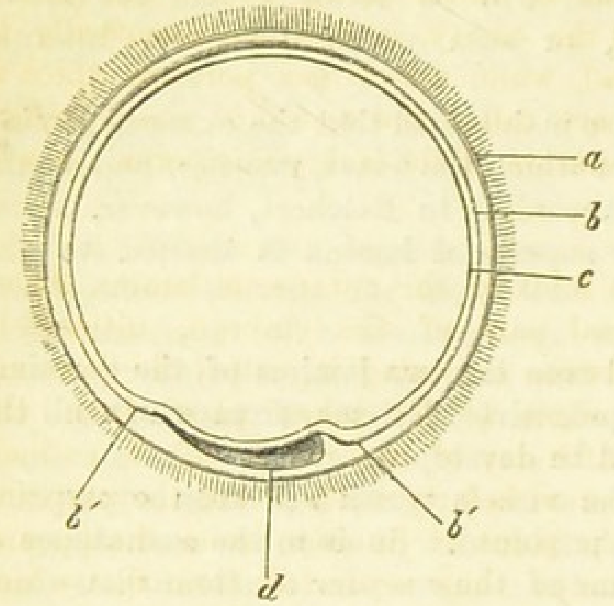
1018. **Blastema.**—Between the two laminæ of the germinal membrane appears the primitive blastema, from which all the organs of the embryo will be developed.

From this blastema the vessels which will soon overspread the mucous lamina are produced. It is to the assemblage of these vessels that the name of the *vascular membrane* has been applied, although it has none of the characteristics of a true membrane.

1019. **First Appearance of the Embryo.**—While the germinal membrane is thus resolved into two laminæ, the embryonic spot, elongated as already described into the form of an oblong ellipse, increases in thickness, and forms a ridge upon the external surface of the germinal membrane. Its extremities as well as its sides are bent so as to present a concave surface towards the centre of the egg, and to give the whole the form of a boat, the keel of which is presented outwards. One end of this boat, representing the stern, is greater than the other, which represents the bow. The former called the *cephalic* extremity, corresponds to the head of the future embryo, and the latter, the *caudal* extremity, to the lower part of the body. The sides of the boat-shaped mass gradually approach each other so as to convert the whole into a sort of tube with a longitudinal opening in it from end to end. This corresponds to the thoracic and abdominal cavity of the future animal. The space between the edges which thus approach each other corresponds to the umbilical opening. In the mass thus formed, the traces of the spinal marrow, the brain, and the vertebræ are progressively developed.

According as the embryo is gradually bent at its ends and sides into the boat-form here described, the parts of the cutaneous lamina placed upon its limits are raised all around

it. This elevation is most apparent at first towards the cephalic and caudal extremities.



a. Vitelline membrane covered externally with villosities.
b. Cutaneous lamina of germinal membrane.
c. Mucous lamina of germinal membrane.
d. Embryonic mass.
b′ b′. The first elevation of the cutaneous membrane by the cephalic and caudal extremities of the embryo.

Fig. 467.
MAMMIFER'S EGG ABOUT THE TENTH DAY OF EMBRYONIC LIFE (Beclard).

The result of the succession of changes here described is illustrated in fig. 467.

As the progress of development advances, the cutaneous membrane bends itself over the cephalic and caudal extremities of the embryo, and passes under its dorsal part, forming two folds, the edges of which gradually approach each other. This change is illustrated in fig. 468.

a. Vitelline membrane.
b. Cutaneous lamina of germinal membrane.
b′ b′. Edges of folds of the cutaneous lamina approaching each other.
b″ b″. Cephalic and caudal hoods formed by the cutaneous membrane bent over the extremities of the embryo.
c. Mucous lamina of the germinal membrane retiring from the cutaneous lamina, and forming the umbilical vesicle.

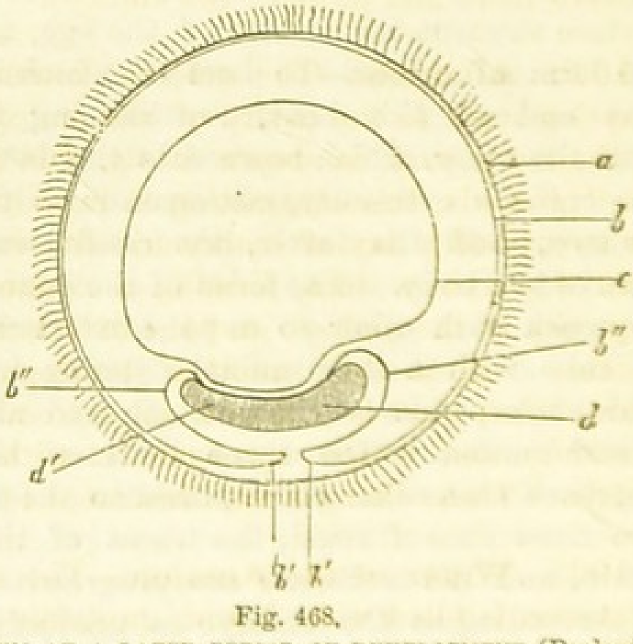


Fig. 468.
OVUM AT A LATER PERIOD OF DEVELOPMENT (Beclard).

1020. **Umbilical Vesicle.**—According as the embryo curves

itself so as to increase the concavity directed towards the centre of the egg, the mucous lamina enters the cavity of the embryo, adapting itself to its form as shown in fig. 468. The part of this lamina which enters the cavity, is destined eventually to form the intestinal canal, while the larger portion, which is outside ($b'' \ b''$), forms a part called the *umbilical vesicle*, which disappears before the expiration of the embryonic period, as will presently be shown.

1021. **Amnion.**—The folds of the cutaneous lamina which are bent under the dorsal part of the embryo, ultimately unite and form a membrane enclosing it, called the *amnion*. The junction of the edges ($b' \ b'$) takes place from the twentieth to the twenty-fifth day of embryonic life in animals whose mean embryonic period is forty weeks,* and the partition which at first exists at the point of junction soon disappears. The remainder of the lamina thus separated from that which forms the amnion attaches itself to the vitelline membrane, and is incorporated with it, forming the general coating of the egg, now called the *chorion*, the surface of which is covered over with villosities as indicated in fig. 468.

At first the amnion surrounds only the dorsal and terminal parts of the embryo, as shown in fig. 468, but as the umbilical orifice is more and more contracted by the mutual approach of the ventral plates, the amnion, drawn together by the edges, encloses more and more of the embryo.

1022. **Allantois.**—The mucous lamina, as already stated, adapting itself to the cavity of the embryo, contracts its width at the lower part, as shown in fig. 468 ; but as the development proceeds, this contraction is rapidly increased, and about the twenty-fifth day of embryonic life it is reduced to a comparatively narrow duct, forming a communication between the concavity of the embryo and the external part of the umbilical vesicle. Meanwhile another development of the mucous lamina takes place near the caudal extremity, which is called the *allantois*, and which corresponds with the future urinary vesicle. These changes are illustrated in fig. 469.

1023. **Water of the Amnion.**—The amnion soon after its formation is filled with liquid, probably secreted like that of

* Unless otherwise expressed, we shall take the whole embryonic period as forty weeks.

serous membranes, in which the embryo floats until the transition from embryonic to natural life. This liquid, which is called the *water of the amnion*, consists of ninety-nine per cent. of water, combined with a small proportion of albumen, chloride of sodium, phosphate and sulphate of lime, and other salts. It continues to increase in quantity till the fifth month, at which epoch it is about equal to the weight of the embryo. After this, the quantity remaining the same, the embryo increases in volume. At the moment of transition from embryonic to natural life, the liquid is discharged by the rupture of the amnion, and is then from one to two pints in quantity.

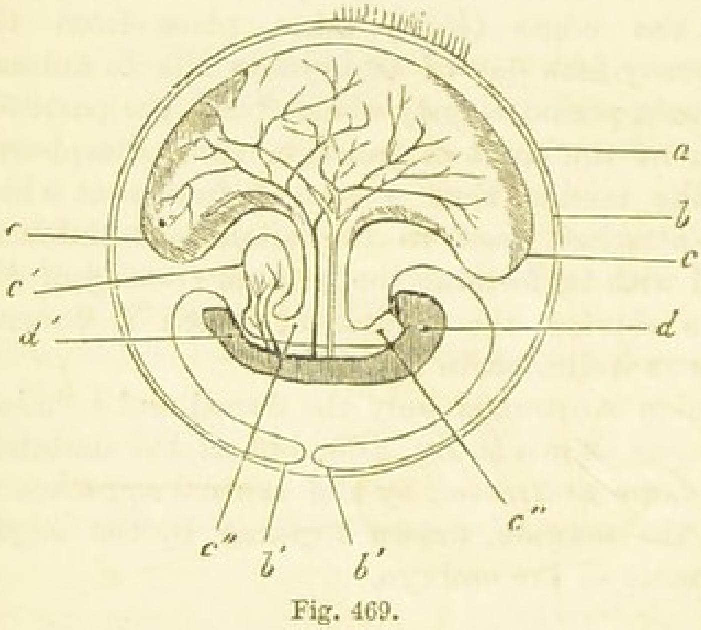


Fig. 469.

MAMMIFER'S EGG ABOUT THE TWENTY-FIFTH DAY OF EMBRYONIC LIFE (Beclard).

a, b. Chorion, composed of the union of the vitelline membrane and cutaneous lamina.
b', b'. Folds of the cutaneous lamina closing to form the amnion.
c, c. The umbilical vesicle with its blood-vessels.
d. Cephalic part of embryo.
d'. Caudal part of embryo.
c'. Allantois, with its blood-vessels.
c''. First vestiges of the intestinal cavity of the embryo, formed by part of the mucous lamina communicating with the extra-embryonic part of the umbilical vesicle, *c, c,* by a narrow neck.

The narrow neck connecting the umbilical cavity with the umbilical vesicle is called the *omphalo-mesenteric duct*, and the blood-vessels distributed over the vesicle are called the *omphalo-mesenteric vessels.* In like manner the blood-vessels distributed over the allantois (*c'* fig. 469), are called the *allantoid vessels.* These, at a later period, become the *umbilical arteries* and *vein.*

The umbilical vesicle is only a temporary organ, which disappears at a subsequent epoch of embryonic life, the omphalo-mesenteric duct closing, and the vesicle wasting away. Before this, it contributes to the circulation of the embryo. At the close of the first month of embryonic life it fills the chief part of the interior of the egg, and has then a magnitude equal to that of a pea. About this period, the omphalo-mesenteric

duct closes, and the vesicle disappears by re-sorption in proportion as the egg increases.

While the umbilical vesicle decreases and wastes away, the allantois increases rapidly, until it completely fills the egg, coming into contact with every part of the chorion. This state of the egg is illustrated in fig. 470.

The development of the allantois is very rapid. At the moment when the umbilical contraction of the embryo reduces the communication between the intestine and the umbilical vesicle to a narrow duct, the allantois is contracted immediately

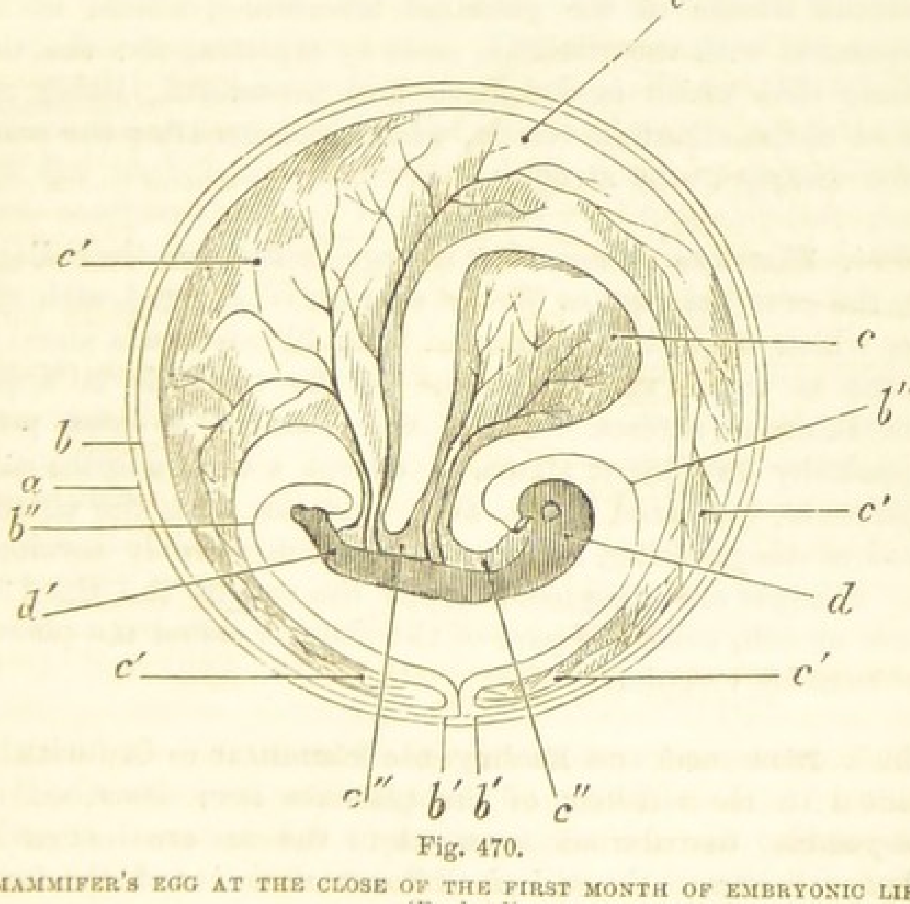


Fig. 470.

MAMMIFER'S EGG AT THE CLOSE OF THE FIRST MONTH OF EMBRYONIC LIFE (Beclard).

a, *b*. Chorion.
b′, *b′*. Union of the folds of the cutaneous lamina.
b″, *b″*. Cephalic and caudal hoods.
c. Umbilical vesicle decreasing in magnitude.
c′, *c′*, *c′*, *c′*. Allantois increased so as to fill the egg in contact with the chorion.
c″, *c″*. Incipient intestine of the embryo.
d. Cephalic extremity.
d′. Caudal extremity.

above the caudal part of the embryo, and is thus divided into two unequal parts, separated by a narrow intermediate duct. The part of the vesicle included within the duct, and situated

consequently in the abdomen of the embryo, is intended at a later period to form the urinary bladder, and the part exterior to the same narrow duct, and above it in the figure, constitutes the allantois properly so called.

When the allantois spreads over the internal surface of the chorion, it is gradually incorporated with it. Some physiologists maintain that the chorion is not, properly speaking, formed by the combination of the successive membranes here mentioned, but that each atrophises and wastes away, when that which is within it is formed. According to Coste, the first chorion consists of the vitelline membrane ; the second of the cutaneous lamina of the germinal membrane, which, at first incorporated with the vitelline, ends by replacing it ; the third chorion, that which is definitive and permanent, being constituted of the allantoid vesicle, which remains after the second chorion disappears by atrophy.

1024. **Placenta.**—Soon after the egg issues from the Fallopian tube, the external surface of the chorion is covered with villosities, which begin to be crowded with blood-vessels about the moment at which the membrane of the allantois is applied to its internal surface. These villosities at a later period disappear by atrophy at all parts, except a certain space called the *placenta*, indicated in fig. 469. At this part, the villosity, instead of disappearing, increases, and is considerably developed. These changes are completed about the end of the third embryonic month, when the part of the chorion called the placenta alone remains vascular.

1025. **Maternal and Embryonic Placentas.**—In immediate contact with the villosity of the placenta here described is a corresponding vascular arrangement in the maternal organism, the latter being distinguished as the *maternal* and the former as the *embryonic placenta.* The villosities of the fœtal placenta (in the human species) are received in tufts into depressions in the walls of the vessels of the maternal placenta, which are enlarged into cavities or reservoirs of blood. By this admirable provision, the functions of the maternal circulation are shared by those of the embryonic, an interchange taking place between the maternal and embryonic blood through the coats of the vascular structure of the two placentas by endosmose, so that the embryonic blood is arterialised and nourished by the mediate action of the maternal pulmonary and digestive organs.

Since the placenta, therefore, discharges the functions of nutrition and respiration in the embryonic economy, it may be expected that its magnitude shall bear some relation to that of the embryo. It is accordingly found that it increases with the increase of the embryo, and maintains with the maternal organism connections more and more numerous according as the growth of the embryo proceeds. As embryonic life advances, the allantois, being converted into a twisted cord called the *umbilical cord*, forms the vascular connection between the embryo and the placenta, consisting, as will presently appear, of two arteries and a single vein, called the *umbilical arteries* and the *umbilical vein*, having their terminations in the villosities of the embryonic placenta. The membrane of the amnion, also, after it has advanced from the cephalic and caudal extremities of the embryo towards the umbilical region, attaches itself upon the umbilical cord, of which it forms a sort of sheath which continues to the termination of the embryonic period. The manner in which the umbilical arteries and vein contribute to the circulation of the embryo will be presently explained.

1026. **Development of the Embryo.**—While the succession of changes here described are taking place in the umbilical vesicle, the allantois, the amnion, and other appendages of the embryo, the body of the embryo itself is gradually assuming the organised form proper to the future animal. The embryonic spot rapidly increasing, first assumes the form of the embryo ; the several tissues and organs then begin to be formed and developed, and in due time the embryo, attaining a certain degree of organic perfection, emerges from its embryonic state into that of natural life. The duration of the embryonic period varies in different species, as will be presently explained.

The rudiments of the cerebro-spinal nervous system of the future animal are the first indications of organic form, traced upon the germinal spot at a moment when this spot consists of nothing more than a stratum of cellular structure interposed between the cutaneous and mucous laminæ of the germinal membrane. This cellular mass presents along its centre a clear line, surrounded at either side and at its ends by two salient ridges, which arise from the accumulation of blastema on the borders of the primitive line (fig. 471).

1027. **Formation of Spinal Cord.**—The primitive line indicated in the figure, and the dark margin which surrounds it, form

a sort of hollow groove, the bottom of which is represented by the bright part. The obscure borders, called the *dorsal laminæ*, become more and more curved, so that their edges approaching each other, are at length united along the median line, converting what was first a hollow groove into a hollow tube. This tube is the vertebral canal of the embryo. A nervous laye., which forms the inner part of the dorsal laminæ, is fashioned into an inner tube which is the rudiment of the brain and spinal cord.

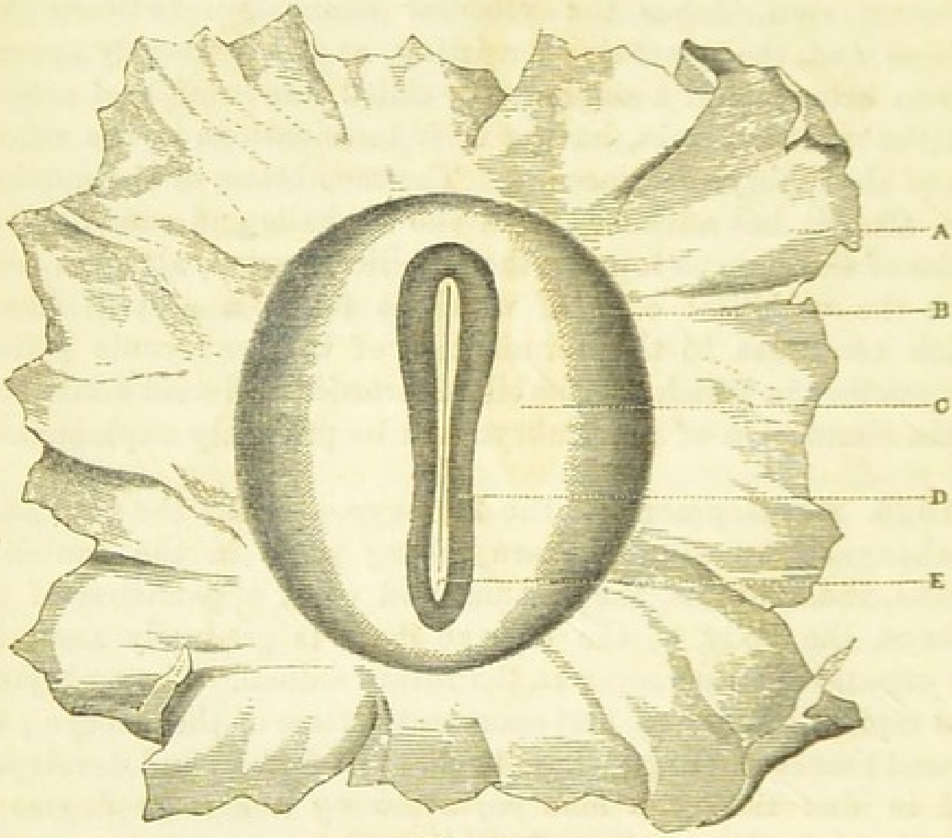


Fig. 471.

PART OF THE GERMINAL MEMBRANE OF THE OVUM OF THE DOG, SHOWING THE AREA PELLUCIDA AND RUDIMENTS OF THE EMBRYO, MAGNIFIED TEN DIAMETERS (Bischoff).

A. Germinal membrane.
B. Area vasculosa.
C. Area pellucida.
D. Dorsal laminæ.
E. The primitive groove bounded laterally by the pale pellucid substance of which the central nervous system is composed.

1028. **The Brain.**—At its cephalic or anterior extremity the primitive nervous system has a slight enlargement, which is the first vestige of the future brain. Upon this, according as it is developed, are traced three distinct enlargements, called the *cerebral cells*, separated one from another by contractions. These, increasing unequally in the progress of development, subsequently produce different parts of the encephalon (fig. 472).

The primitive groove (A), is not yet closed, and at its cephalic extremity the three dilatations (B) here mentioned are indicated. These correspond to three divisions or vesicles of the brain. At its caudal extremity the groove presents a lancet-shaped dilatation (C), called the *sinus rhomboidalis.* The margins of the groove consist of a clear, pellucid, nervous substance,

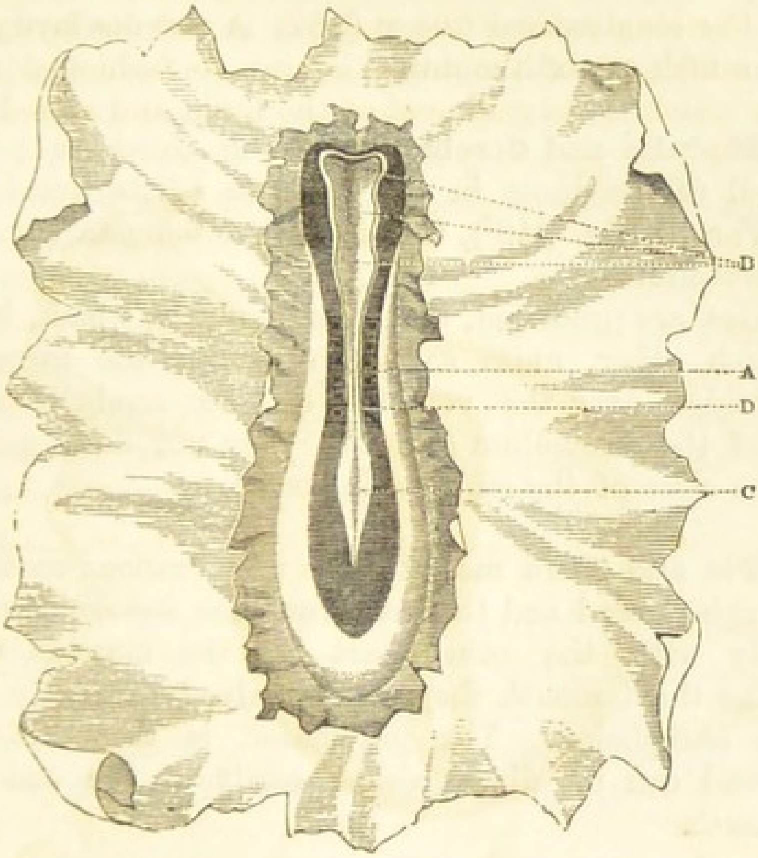


Fig. 472.

PART OF THE GERMINAL MEMBRANE OF THE DOG IN A MORE ADVANCED STAGE OF DEVELOPMENT (Bischoff).

and along its bottom is traced a faint streak, which is probably the *chorda dorsalis*, or incipient centre of the vertebral column. The vertebral plates (D), are arranged on either side. The anterior of these three cells, increasing rapidly in volume, produces severally and successively the cerebral hemispheres, the lateral ventricles, (326), the optic thalami (fig. 241^3), corpus callosum (fig. 241), and the fornix (fig. 241^6).

The development of these important parts of the nervous system commences about the end of the first month. Towards the fourth month, all the parts are clearly traced, and the cerebral lobes, which continue to increase, soon cover the posterior parts of the encephalon which are evolved from the middle and posterior cells (B). Thus, about the fifth month the quadrigeminal bodies (333), and about the seventh the cerebellum (331), are covered by the cerebral hemispheres. It is about the

fourth month that the convolutions and anfractuosities of the brain (fig. 240) begin to be traced upon the hemispheres.

The middle cerebral cell, which at the commencement was largest, increases less rapidly than the others. It is from this that the quadrigeminal bodies and the Sylvian aqueduct are evolved. The longitudinal fissure (322) is not distinctly traceable till the fifth or sixth month.

1029. **Medulla and Cerebellum.**—The third or posterior cerebral cell (B) produces in the progress of its development the pons Varolii (fig. 240[2]), the medulla oblongata (fig. 240[1]), and the cerebellum.

Two plates are produced, one at either side, which, bending towards each other, unite so as to assume the form of a nervous bridge over the ventricle of the cerebellum. The foliations of the cerebellum (fig. 244[17]) are not developed until towards the close of the embryonic period.

1030. **Pia and Dura mater.**—The membranous coats which cover the spinal cord and the cerebrum, are developed contemporaneously with the other part of the nervous system. Towards the third month they are perceived distinctly enough upon the encephalon. The pia mater is that which first appears, and can be distinguished easily at the end of the second month.

1031. **The Spinal Nerves** are developed in their natural position, and do not, as has been maintained by some anatomists and physiologists, issue from the cord and the cerebrum by a sort of budding, like that of vegetables ; nor is it less incorrect to state that, when once formed, they direct themselves towards the cord and the cerebellum. They are formed, like the other parts of the nervous system in their natural position, from the general blastema, distributed between the cutaneous and mucous laminæ of the germinal membrane, and the same is true of the great sympathetic system.

1032. **The Eyes.**—The organs of sense are severally developed from the cellular structure of the encephalon. Each organ may be regarded as a mere expansion of the corresponding nerve. Thus, the two eyes result from the subdivision of a single cell, which is a sort of hollow emanation of the anterior cerebral cell (B, fig. 472). When the two ocular

cells are once formed, their anterior parts being of nervous structure, are reflected inwards upon the eye, and it is from these, spread over the interior surface of the organ, that the retina is formed. The other parts of the eye, within and without, are developed in like manner from the surrounding blastema. In this way the sclerotica and the cornea, the choroid, the iris, and the transparent humours are severally formed. The choroid is at first continuous, the iris not being yet perforated by the pupil. It is not till the seventh month that the central part of the iris disappears, leaving open the aperture, called the pupil.

Till the beginning of the third month the eyes are entirely covered by the skin, which, from this time becoming thinner and thinner, assumes the character of the conjunctiva. About the same time, the upper and lower eyelids are developed in the form of cutaneous bands, which go on increasing until the fourth month, when they cover the whole globe of the eye.

1033. **The Olfactory Organ** consists of an excrescence of the anterior cerebral cell (B, fig. 472), forming the olfactory nerve, and its bulb, which in the beginning is hollow. The mucous membrane of the nose proceeds from the cutaneous lamina—a part of which is enclosed by the development of the facial bones.

1034. **The Organ of Hearing** proceeds from the third or posterior cerebral cell (B). This cell, when developed, forms the nervous and membranous parts of the internal ear, and around it the bony parts are developed. About the third month the semicircular canals and cochlea, and also the external auditory meatus, and the concha are distinguishable. The meatus and the cavity of the tympanum are formed by the increase and development of different parts of the face.

1035. **Vertebræ and Thorax.**—Soon after the first appearance of the spinal groove (fig. 471), there appears at either side of it a series of small quadrilateral plates arranged closely together, which, being cemented to the middle and anterior part of the spinal cord, form the bodies of vertebræ. A little later the vertebral plates in the posterior part of the blastema are formed. They soon unite along the median line and upon the sides of the bodies of the vertebræ, and thus the

vertebral canal is completed. The ribs and the sternum appear later. When the abdominal and thoracic cavities are formed by the curvature of the sides of the embryo, and the umbilical opening is clearly traced, the costal lines and the sternum are perceived in progress of development in the blastema interposed between the cutaneous and mucous laminæ of the germinal membrane. It is about the sixth month of the embryonic life that the ribs and sternum are formed.

1036. **The Skull** is nothing more than a development of the superior vertebræ of the column. At a certain period its first vestiges can be traced in correspondence with the three principal divisions (B), which are severally designated the anterior sphenoidal vertebra, the posterior sphenoidal vertebra, and the occipital vertebra. The several bones of the skull are then formed progressively, and remain either in the state of distinct bones or are cemented to those previously formed.

1037. **Neck and Trunk—Mouth, Nose, Ears.**—The different parts of the neck and trunk, are like the other parts, developed in the blastema, included between the laminæ of the germinal membrane. While the sides of the embryo are curved towards the centre of the egg, forming continued plates, and surrounding the abdominal and thoracic cavity, the parts which correspond to the neck and face consist not of plates but of tubercles, three at each side, which, being developed, form between them three openings. The tubercles take the form of three arches, called *branchial arches*, the development of which forms the jaws, with the teeth, the tongue, the soft parts of the face, the ossicles of the ear, the hyoid bone, the larynx, and the soft parts of the neck. The natural cavities of the face are formed by the parts of the original cavity of the embryo, bounded by parts developed from the tubercles. The first branchial cavity forms a sort of cloaca, common to the mouth and the nasal cavities, but which is soon afterwards limited and shaped by the development of the maxillary bones and the nasal septum. The cavity of the tympanum of the ear, and the external auditory meatus proceed from the second opening, shaped by the development of the tubercles.

1038. **The Limbs.**—The pelvis, like the other parts, is formed from the interposed blastema. The limbs are developed early ; and begin to make their appearance at the end of

the first month. They appear, at first, under the form of small stumps on each side of the trunk, having flattened extremities which constitute the rudiments of the future feet and hands. About the sixth week, the limbs having increased in length, the flattened terminal parts present four grooves, or incisions, which indicate the separation of the fingers and toes.

1039. Ossification commences in the bones at an early period; but during the greater part of embryonic existence, they are more or less cartilaginous, and do not acquire their full hardness and strength until long after birth.

1040. **The Muscles** are traced in the blastema of the trunk and members, in their natural positions, about the end of the second month. The first seen are those of the vertebral column, a little later those of the neck, then those of the abdomen, and finally those of the members and face.

1041. **The Skin** is formed from the cutaneous lamina of the germinal membrane, which covers the whole external surface of the embryo. This lamina may indeed be regarded as the primordial skin. As early as the second month the flattened and polygonal cells of the epidermis are distinguishable. In the third month the sudorific and other glands, as well as the rudiments of the nails, appear. The papillæ of the skin are distinguished about the fourth month. The hair is seen about the same period, under the form of a downy wool, and the eyebrows and eyelashes are developed about the sixth month.

1042. **The Digestive Canal** has its origin in the cavity of the boat-shaped body of the embryo already described. The intestinal sac enclosed within this first appears closed both at the cephalic and caudal extremities, communicating with the umbilical vesicle and allantois by the narrow ducts already described. Its communication with the umbilical vesicle corresponds with a point near the termination of the small intestine, and its connection with the allantois with the anal part of the intestine. These communications with the umbilical vesicle and allantois are soon obliterated, and the intestine becomes for the moment a tube closed at both ends. Being at first straight it soon takes the looped form, and is maintained posteriorly by a fold of new formation, which subsequently becomes the mesentery. The cephalic extremity of this closed tube, being enlarged, forms the stomach.

1043. **The Mucous Membrane** which lines the intestine is nothing more than the mucous lamina of the germinal membrane, somewhat modified in its structure. At its surface appears a cylindrical epithelium, and within its thickness villosities and glands. The muscles which line the digestive tube, the serous membrane which covers both it and the abdominal cavity now formed, proceed from the blastema accumulated between the germinal laminæ.

1044. **The Œsophagus** is formed from the same source; it soon opens at one extremity into the stomach, and at the other into the mouth. At its inferior extremity the digestive tube is placed in connection with a depression in the cutaneous envelope, called the *rectal depression*, and the septum by which they are separated soon disappearing, the entire intestinal canal is opened as well at its inferior as at its superior extremity.

1045. **The Liver and the Pancreas** are developed in the blastema beside the digestive canal. In the glandulous mass of the liver the excretory duct is seen developed, opening into the intestinal canal. The trachea and the lungs also make their appearance, but separately, in the interposed blastema; the communications with the pharynx are, however, soon formed.

1046. **Vascular System.**—While the organs and tissues of the embryo are thus developed, the vascular system is formed, its first vestiges appearing nearly as soon as the spinal cord. These, like the other parts of the body, are formed out of the cellular mass of blastema, evolved between the laminæ of the germinal membrane.

The first rudiments of the circulatory apparatus consist of blood-vessels which overspread the mucous lamina, and form upon it a circle nearly complete, called the *terminal sinus*, from which ramifications issue, communicating with the body of the embryo and others which cover the entire extent of that part of the germinal membrane which is soon converted into the umbilical vesicle. These vessels are placed in relation with the heart of the embryo, simultaneously developed near its cephalic extremity.

1047. **The Primitive Embryonic Circulation** may not inaptly be denominated umbilico-vesicular, since its purpose seems to be to supply nutrition to the embryo, by a system of

vessels which overspread the entire surface of the umbilical vesicle, and anastomose with the vessels of the villosity of the chorion. The vessels which issue from the superior part of the rudimentary heart are called *aortic arches*, and are curved downwards, being applied along the direction of the vertebral column. They separate at the umbilical opening into two arterial trunks, the ramifications of which overspread the umbilical vesicle. These, called *omphalo-mesenteric arteries*, throw out ramifications which extend to the terminal sinus. From this a system of veins issue, called *omphalo-mesenteric veins*, which ultimately unite in two trunks, entering the body of the embryo. The blood, issuing from the heart through the omphalo-mesenteric arteries, is carried by them to the terminal sinus, and brought back by the omphalo-mesenteric veins.

This first embryonic circulation will be rendered more intelligible by the theoretical diagram, fig. 473.

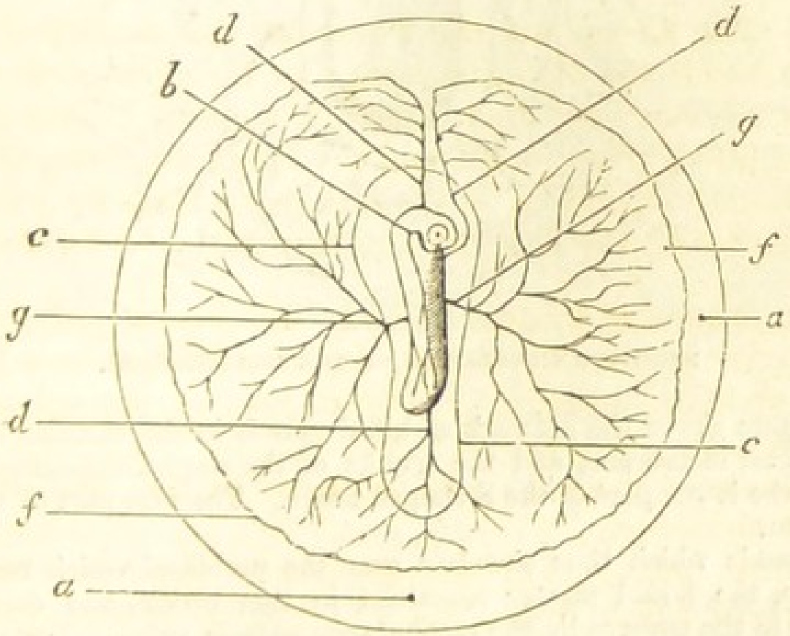


Fig. 473.

PRIMITIVE EMBRYONIC CIRCULATION.

a, a. Vitellus or yolk.
b. The heart.
c, c. Amnion.
f, f. Terminal sinus.
d, d, d. Omphalo-mesenteric veins.
g, g. Omphalo-mesenteric arteries.

The aorta divides into two omphalo-mesenteric arteries, *gg* right and left, which ramify over the germinal membrane until they reach the terminal sinus *f*. The blood is brought back by the mesenteric veins which coalesce in the trunks *d d*. Subsequently, other veins are developed in the vascular network, and, at length, when the germinal membrane has enclosed the whole yolk, the terminal sinus entirely disappears, and the yolk sac becomes covered with blood-vessels.

As a further illustration of this primitive embryonic circulation, we give that of the dog in the 23rd or 24th day of the embryonic period, magnified 10 diameters, in fig. 474.

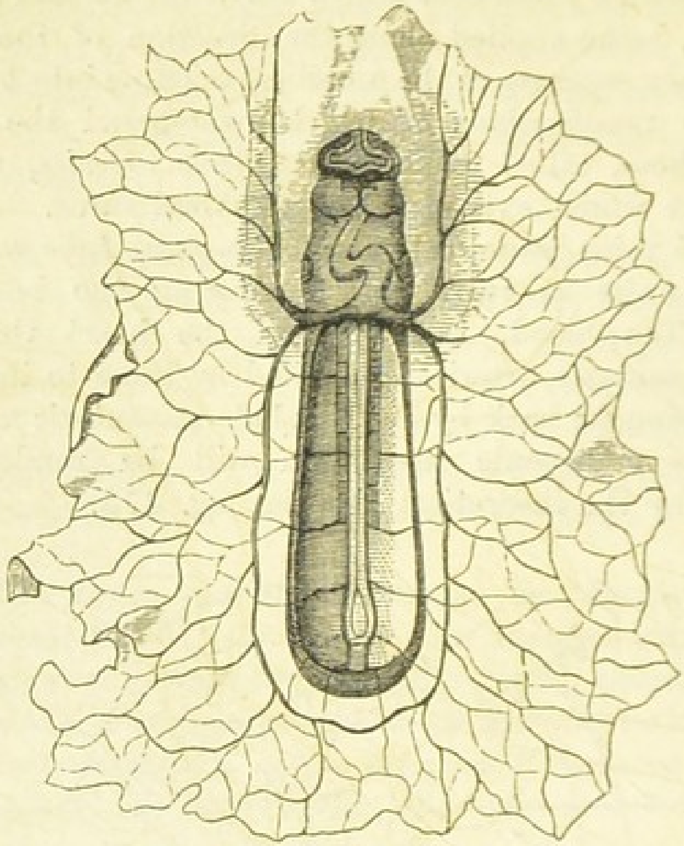


Fig. 474.

PRIMITIVE CIRCULATION OF THE DOG (Bischoff).

This figure shows the network of blood-vessels in the vascular lamina of the germinal membrane, and the trunks of the omphalo-mesenteric veins entering the lower part of the S-shaped heart. The first part of the aorta is also seen.

The vessels which thus circulate over the umbilical vesicle receive, by absorption, the liquid matter contained in this vesicle, and carry these materials to the embryo by the omphalo-mesenteric veins. The umbilical vesicle and its vessels thus play, to a certain extent, the part with relation to the embryo which is afterwards performed by the placenta.

1048. **The Second Embryonic Circulation** commences when the communication between the intestine and the umbilical vesicle disappears. The omphalo-mesenteric vessels, reduced at first to a single artery and a single vein, atrophise, and finally disappear with the vesicle itself. The intra-embryonic portion of the omphalo-mesenteric vein continues to receive the venous blood of the intestines by the mesenteric vein, which latter forms the trunk of the portal vein. As a prelimi-

nary to the establishment of the second circulation, the allantois increases with the decrease of the umbilical vesicle.

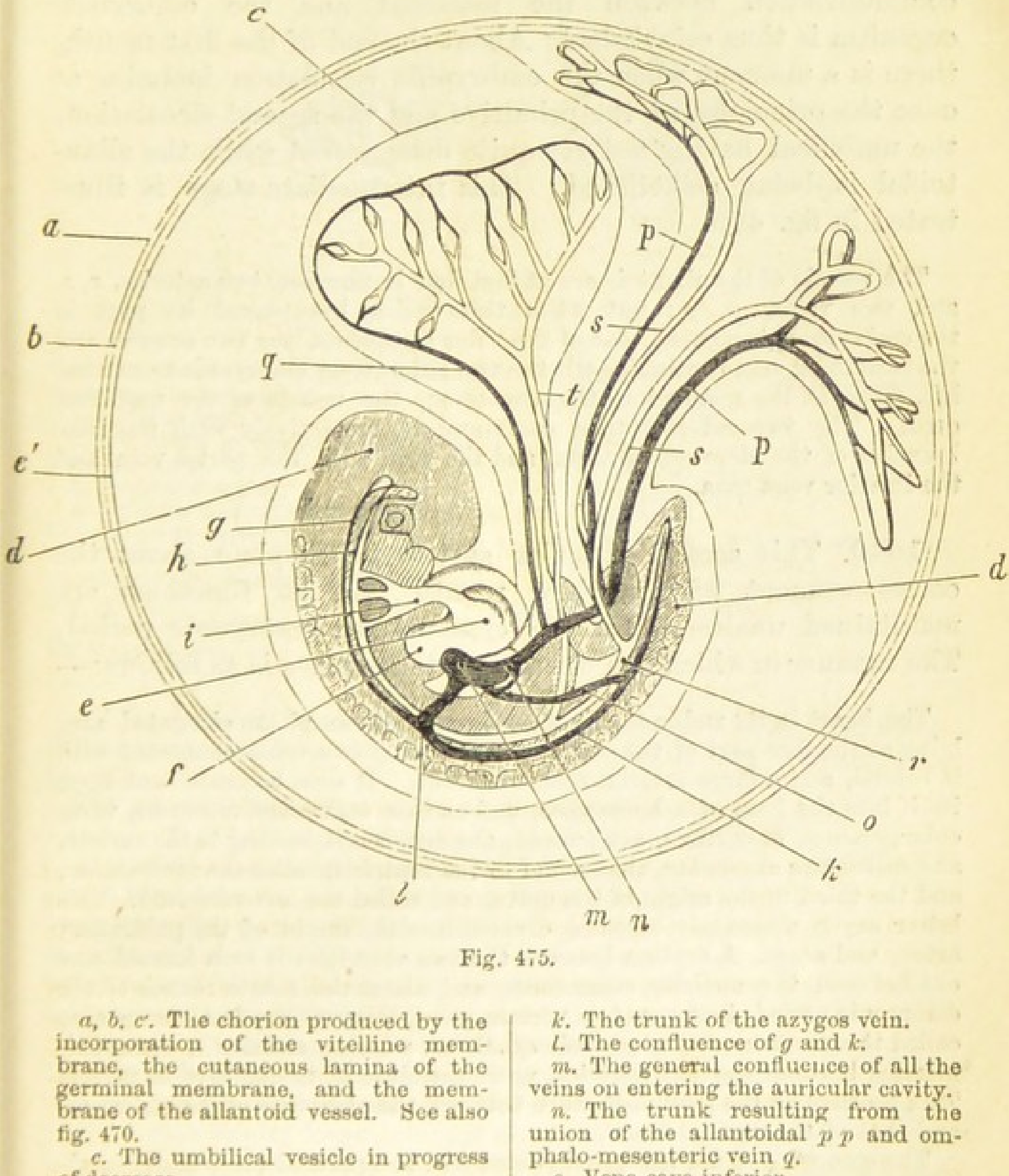


Fig. 475.

a, b, c'. The chorion produced by the incorporation of the vitelline membrane, the cutaneous lamina of the germinal membrane, and the membrane of the allantoid vessel. See also fig. 470.

c. The umbilical vesicle in progress of decrease.

d. The cephalic, and *d'* the caudal extremity of the embryo.

e. The ventricular, and *f*, the auricular cavity of the heart.

i. The aorta forming the arcs.

h. The thoracic aorta.

g. The trunk which ultimately forms the vena cava superior.

k. The trunk of the azygos vein.

l. The confluence of *g* and *k*.

m. The general confluence of all the veins on entering the auricular cavity.

n. The trunk resulting from the union of the allantoidal *p p* and omphalo-mesenteric vein *q*.

o. Vena cava inferior.

p, p. Allantoidal veins.

q. Omphalo-mesenteric vein.

r. Abdominal aorta.

s, s. Allantoidal arteries.

t. Omphalo-mesenteric artery.

No sooner has the allantois appeared than its surface is

covered with vascular ramifications which extend to the internal surface of the chorion, with vascular ramifications of the villosity of which its vessels anastomose at the periphery. The vascular communication between the maternal and the embryonic organism is thus established. About the end of the first month, there is a moment when the embryonic circulation includes at once the principles of the primitive and the second circulation, the umbilical having not yet quite disappeared while the allantoidal is being established. This intermediate stage is illustrated in fig. 475.

The vessels of the allantois are at first four in number, two arteries, *s*, *s*, and two veins, *p*, *p*; but when this vesicle has played its part in the embryonic phenomena, one of the veins atrophises, the two arteries and the remaining vein continuing till the transition from embryonic to natural life, form, at the moment of the transition, the vessels of the umbilical cord. The two arteries then communicate respectively with the iliac branches of the descending aorta, and the vein with the portal vein and the inferior vena cava.

1049. This second vascular system is complete about the commencement of the third month, and its functions are maintained unaltered till the close of the embryonic period. The manner in which the circulation takes place is as follows:—

The heart in its rudimentary state has the form of an elongated sac, lying at the fore-part of the embryo, and having two veins connected with it behind, and a large arterial trunk in front. It soon becomes bent upon itself into the form of a horse-shoe, and as this curvature increases, three enlargements, or cavities, are formed, the first corresponding to the auricle, and called the *auricular*, the second to the ventricle, called the *ventricular*, and the third to the origin of the aorta, and called the *arterial bulb*. This latter cavity ultimately becomes divided into the origin of the pulmonary artery and aorta. A septum between the two ventricles is soon formed, and one between the auricles commences, and about the fourth month of the embryonic period, increases to a certain point, leaving, however, an opening called the *foramen ovale*, or *hole of Botal*, which maintains a communication between the two auricles, until the close of the embryonic period. This constitutes the main difference between the structure of the embryonic and that of the natural heart.

The structure of the embryonic heart will be rendered more easily intelligible by fig. 476, where A exhibits a front, and B a back view of the heart, at about the fifth week of the embryonic period.

In the progressive development of the vascular system, the aortic arches proceeding towards the cephalic extremity are multiplied and form a certain number of secondary arches, which correspond to the formative tubercles of the face and neck (1040); these arches, being modified, produce the cross of the aorta, the pulmonary, subclavian, and carotid arteries, and their branches. It is important to observe, however, that a large communication, called the *arterial duct*, exists during the embryonic period

between the aorta and the pulmonary artery, which is not obliterated till the transition takes place from embryonic to natural life.

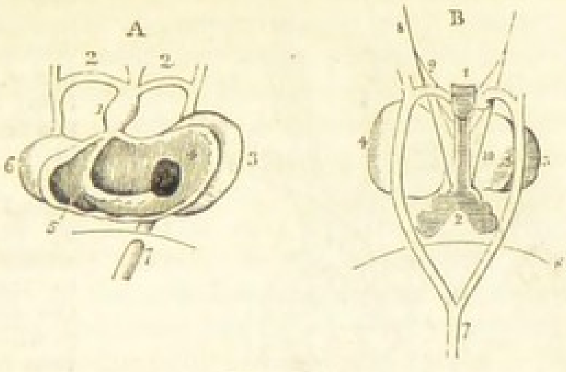


Fig. 476.

A. The heart seen on the ventral aspect and laid open.
1. Arterial bulb.
2, 2. Arterial arches which unite behind the aorta.
3. Auricular region.
4. Opening leading from auricular, 3, to ventricular cavity, 6.
5. Septum of the ventricles commencing to be formed on the floor of the cavity.
7. Vena cava inferior passing through the diaphragm.

B. Back view, with the rudiments of the respiratory organs.
1. Larynx and trachea.
2. Lungs.
3. Ventricular, and
4. Auricular part of the heart.
6. Diaphragm.
7. Descending aorta formed by the union of the right and left aortic arch.
8, 9, 10. Trunk and branches of pneumo-gastric nerves.

All the circumstances attending this second embryonic circulation, which continues to the close of the embryonic period, are illustrated in fig. 477.

The arrows indicate the course of the blood along the several blood-vessels. The blood of the superior cava c^* mostly descends through the right auricle *r*, as shown by one arrow, into the right ventricle v^*. That of the inferior cava *c*, ascends through the right auricle *r*, passes, as shown by another arrow, into the left auricle *l*, and thence into the left ventricle *v*. The course of the blood from the right ventricle into the pulmonary artery *p*, and ductus arteriosus *o*, and from the left ventricle into the aorta, *s*, is shown by two dotted lines.

The right auricle *r*, receives its blood from the two venæ cavæ *c* and c^*. The blood brought by the superior cava c^* is the venous blood which returns from the head and upper part of the body. The inferior vena cava, which is considerably larger, conveys the blood from the lower half of the body, and also that which is sent back from the placenta, through the umbilical vein *u*. This umbilical vein terminates in the figure before its junction with the placenta. The blood which passes through the umbilical vein *u*, has been arterialised in the placenta by endosmose with the maternal organism. This blood passes into the inferior cava *c*, in two different ways, first by the ductus venosus *d*, and, secondly, by the hepatic veins *h*, which receive it after having passed through the liver, to which it was conducted by the portal vein *g*.

The blood supplied by the superior cava c^*, descending over a valve, called the Eustachian valve, and mixed with a small portion of that which

comes from the inferior vena cava, passes into the right ventricle *v**, and

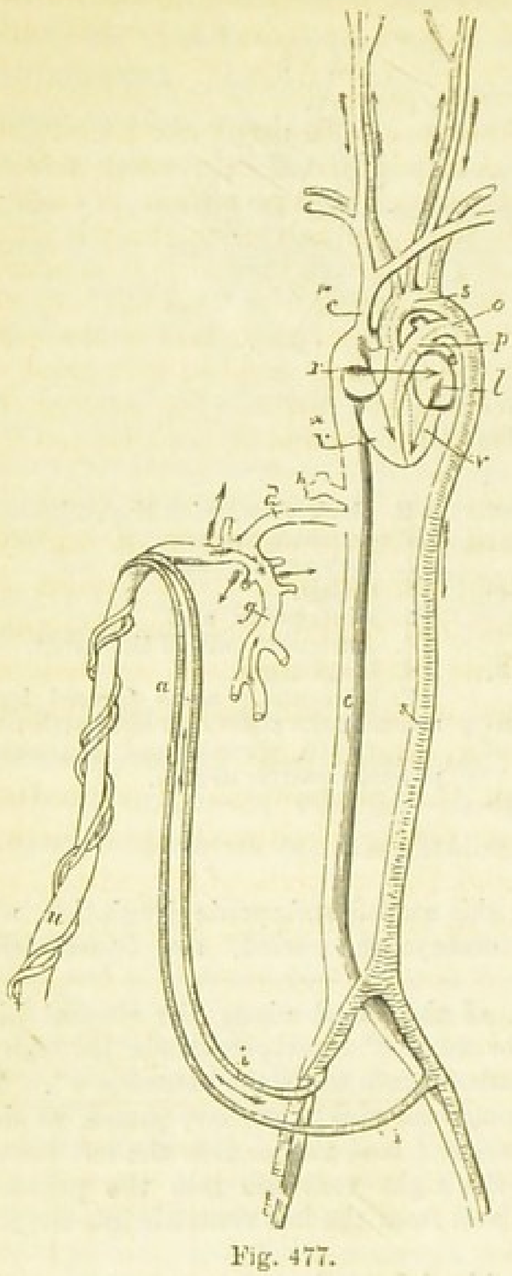


Fig. 477.

ILLUSTRATION OF THE ANTE-NATAL EMBRYONIC CIRCULATION (Sharpey).

s s. The aortic arc and descending aorta; *i i*, the umbilical arteries proceeding from the iliac arteries, which diverge from the lowest point of the trunk *s*, and proceed at *a*, to the umbilical cord winding spirally round the umbilical vein, *u*, the continuation of which (not represented in the figure) goes to the embryonic placenta in which the arteries and vein ramify.

u. The umbilical vein.

d. The ductus venosus, a branch of the umbilical vein which goes direct to the inferior cava, *c*. but which ceases to exist after birth.

*. The branch of the umbilical vein which joins the vena portæ.

g. The vena portæ, which returns the blood from the digestive organs.

h. The hepatic veins, which return the mixed portal and placental blood after its circulation through the liver.

c. The inferior cava.

*c**. The superior cava.

r. Right auricle.

*v**. Right ventricle.

l. Left auricle.

v. Left ventricle.

p. Pulmonary artery.

o. Ductus arteriosus, connecting *p* with the aorta, which ceases to exist after birth.

s. Arch of the aorta.

is thence propelled to the pulmonary artery *p*. A small portion of it is then distributed through the ramifications of that vessel to the lungs, and returns by the pulmonary veins to the left auricle, but by far the larger part passes through the arterial duct *o*, into the aorta *s*, below the origin of the arteries of the head and upper members. This is probably mixed with a small quantity of blood flowing along the aorta, from the left ventricle, and descends, partly to supply the lower half of the body and the viscera, but chiefly to be conveyed along the umbilical arteries *i i*, to the placenta. From all these parts it is sent back by the inferior cava, the vena portæ, and the umbilical vein to the right auricle.

The blood of the inferior cava is partly distributed, as already stated, with that of the superior, but the larger portion directed by the Eustachian valve through the foramen ovale flows from the right *r* to the left auricle *l*, and thence together with the comparatively small quantity of blood returned from the lungs by the pulmonary veins, passes into the left ventricle *v*, from whence it is sent into the arch of the aorta *s*, to be distributed almost entirely to the head and upper members. A certain part of it, however, flows most probably into the descending aorta joining the large stream of blood from the arterial duct. The blood from the upper half of the body is returned by the branches of the superior cava to the right auricle from which its course has been already traced. It will appear from what has been stated, that the chief part of the arterialised placental blood goes to the cephalic half of the embryo, the lower half being chiefly supplied with blood which has already circulated through the head and limbs. The analogy of this part of the circulating system of the embryo to that of amphibia and certain reptiles will be obvious.

1050. **Lower Mammifers.**—The phenomena of embryonic life, explained in the preceding paragraphs, are common (with certain modifications in the marsupial and monotrematous orders) to all mammifers. This class of animals, as their name implies, nourish their young, in the first period of post-natal life, by milk, secreted in the breasts or paps.

The principal differences in the phenomena of reproduction depend upon the number of young produced at a birth, the duration of embryonic life, and the periods of breeding, which are shown in different species in the following table :—

	No. in Brood.	Embryo period weeks.		No. in Brood.	Embryo period weeks.
Cow	1	41	Dog	5 to 6	9 to 10
Horse	1	43	Fox	5 to 6	9
Stag	1	36	Wolf	5 to 6	10
Camel	1	45	Cat	5 to 6	8
Elephant	1	100	Weasel	5 to 6	5
Ass	1	43	Squirrel	5 to 6	4
Ape	1		Rabbit	6 to 8	4
Bear	2	30	Water-rat	6 to 8	
Deer	2	24	Field-mouse	6 to 8	
Bat	2		Ferret	6 to 8	6
Hare	3 to 4	4	Mouse	8 to 10	3
Beaver	3 to 4	17	Pig	12 to 15	17
Mole	3 to 4		Rat	12 to 15	5
Marmot	3 to 4	5	Polecat		9
Guinea pig	3 to 4	3	Sheep		21
Lion	4 to 5	14	Goat		22
Tiger	4 to 5		Zebra		43
Leopard	4 to 5				

1051. **Number of Young in a Brood.**—When animals habitually produce several younglings at a brood, the number

is subject to more or less variation, and those given in the above table are consequently to be taken as averages. The less the number produced, the less will be the variation ; and in animals which produce habitually only a single youngling, the cases of two or more at a birth are always extremely rare and exceptional.

1052. **Multiple Births in Man.**—In general, man comes into the world singly, or one at a birth. The cases of twins are rare, and those in which three or more at a birth are produced extremely exceptional. It appears, by statistical returns made upon a large scale, that upon an average one case of twins occurs in ninety births, and that of three or more at a birth has not occurred more than once in thirty thousand cases.

Rare, nevertheless, as such multiple births are, cases are recorded in which they have occurred with surprising frequency in single families. Thus, a Russian peasant was presented to the Empress Catharine as a natural curiosity, having been the father of ninety children. It is true that this numerous family had not a common mother ; and the most singular circumstance attending the case was, that in several successive marriages the births had been invariably multiple.

1053. **Hypothesis to explain them.**—Physiologists have endeavoured to explain the phenomena of exceptional multiple births by the organic accident of two or more Graafian follicles attaining maturity or bursting and discharging their ova at the same time, or nearly so. The ova thus discharged produce embryos which are simultaneously developed. Another hypothesis is, that two or more ova may happen abnormally to be contained in the same Graafian vesicle. These hypotheses, however, must be taken for what they are worth, being scarcely capable of verification by observation.

1054. **Proportion of the Sexes.**—The human race is distinguished from inferior animals by the independence of the phenomenon of birth on the season of the year. Animals generally produce their young at that season which is most favourable for their development. Children are born at all seasons. Nevertheless, the frequency of births has a marked and well ascertained relation to the course of the seasons. It is found generally in the temperate climates, that births are most numerous in the three winter, and least so in the three summer months. In approaching the colder climates, the

epochs of the maximum and minimum numbers are later, and in approaching the warmer climates earlier.

The number of children which come into the world is not equally shared between the sexes, the male always predominating.

This fact has been established in all countries where statistical registers have been kept; and it is remarkable, that although the numerical proportion between the sexes is subject to some variation from year to year, its mean amount in each country is nearly invariable, though different in one country as compared with another. Thus, on comparing the numbers of male and female children baptised in England and Wales during the first half of the present century, it is found that the number of males invariably exceeded the number of females in a proportion varying, from year to year, from 25 to 50 per 1000; the mean result taken for the whole period showing, that for every thousand girls born, there were one thousand and forty boys.

In France, according to returns extended over 36 years, terminating in 1852, it appears, that for every thousand girls there were one thousand and sixty-one boys born. Thus the preponderance of male births in France exceeds that in England in the proportion of a little more than 6 to 4.

By returns obtained from other countries where accurate statistics are kept, it has been found that the preponderance of male births is intermediate between those of England and France, the number of males being 1050 for every 1000 females.

1055. **Birds.**—The oviparous classes offer great facilities to the researches of the embryologist, in consequence of the ejection of the egg at a very early epoch in the progress of the development of the embryo; and in the class of birds especially these facilities are materially increased by the circumstance of the egg being so easily and conveniently submitted to artificial incubation. It will not therefore be surprising that birds, certain oviparous amphibia, such as frogs and salamanders, and certain reptiles, such as some species of serpents, have been severally, but more especially birds, subjects of the most important and successful researches in this branch of physiology.

Before stating the principal results of these researches directed to the class of birds, it will not be without interest to explain the measures which nature has prompted these animals to adopt, preparatory to the deposition of the egg, for the more effectual preservation of their species—measures which, if not ascribed

to Heaven-sent instinct, would manifest a degree of skill, foresight, and parental solicitude which would do honour to the most intelligent and refined of the human race.

1056. **Nests.**—As the laying season approaches, the bird, as though it were conscious of the coming event, occupies herself in the construction of a dwelling, suited by its materials and form to the little beings to which she is about to give life. Such a structure must fulfil several conditions. In its magnitude and form it must correspond with the magnitude and number of the eggs to be laid, and with the body of the mother who is to sit upon them. It must be so shaped as to keep the eggs securely together, and its materials must be soft, so as not to injure by undue pressure its tender occupants. To prevent the escape of the warmth imparted by the mother, it must be thickly lined with non-conductors of heat. All these conditions are fulfilled with the skill of a natural philosopher.

The nests of the larger class of birds, of hardier nature, are of rude construction ; but those of the smaller species display in a remarkable manner the qualities here indicated. The parents of the coming offspring, father and mother, co-operate in the construction of the nest, for the external part of which straws and twigs are collected, and woven into a sort of basket-work. This not possessing the requisite durability, and allowing, moreover, the air to penetrate and the heat to escape, a quantity of fine clay is collected with enormous labour, and worked into a sort of mastic by means of a viscous fluid secreted by glands placed under the tongue of the bird. With this mastic the parents plaster the interior of the nest, carefully stopping up every crevice and air-hole.

The floor of the nest, however, formed by such plaster, is necessarily hard, and would injure the younglings by its pressure. The parents, therefore, fabricate a carpet, which they spread upon it, over which they place a soft mattrass, the materials of which consist of wool and fine hairs taken from the backs of animals and the cottony parts of certain plants. How countless are the excursions and fatiguing the labour necessary to accumulate, hair by hair and filament by filament, such materials, may be easily conceived. Sometimes the bird strips its own breast of its natural down to form a bed for its young. It is thus that the eider duck provides for the comfort of its offspring, by taking from its own body part of that down which is sought and collected at such cost for the pillow of luxury.

1057. **The Laying** having commenced, and the eggs having been deposited, the mother sits upon them with a constancy so unwearied, that it often affects her health. In some species the two parents share this labour, each allowing the other intervals for refreshing exercise. In other species, while the mother sits upon her brood, the father constantly flies to and fro, bringing nourishment to her, which he presents in his bill with the greatest apparent tenderness. The male of singing birds also often displays his conjugal affection in a still more remarkable manner, by singing beside the nest to wile away the weary hours of the mother of his future offspring.

1058. **The Brood.**—When the young have broken the shell and issued into external life, a new sphere of action succeeds. The parents are now incessantly occupied in providing the family with food, which they swallow in a raw state, taking it into their crop or first stomach, an organ which has been already described (729). There it undergoes a change which renders it suitable to the digestive functions of the young birds, into whose open beaks they disgorge it.

As the younglings acquire strength, the parents often devote themselves to their education. They encourage their first efforts at flight, and teach them where and how to find food. In the case of birds of prey, the parent actually gives the young a series of progressive lessons in the manœuvres necessary for the seizure of its prey.*

1059. **The Embryonic Development of the Bird** consists of three distinct periods : the period of the ovary, the period of the oviduct, and the period of the incubation.

In the first the germ is produced and invested with the germinal vesicle, the yolk, and the yolk sac. The theatre of these phenomena is the ovary.

In the second, the egg is rendered capable of embryonic development, and is invested with the white or albumen, the shell and certain membranes inclosing these. The theatre of these phenomena is the oviduct.

In the third, the embryo is organised from the materials included in the shell ; and at its close the young bird, breaking the shell, issues into external life. The phenomena of this period are produced by the warmth of the maternal body in the

* Lardner's Museum of Science and Art, vol. VIII. p. 166.

act of incubation, and by the action of the atmosphere in contact with the shell.

1060. **The Ovary** (fig. 478), like that of mammifers (fig. 460), consists of an assemblage of ovicapsules, called also ovisacs or calyces, in each of which an egg is produced.

When the egg has arrived at a certain stage of development, being considerably augmented in magnitude, the calyx bursts, and the egg is expelled and enters the superior end of the oviduct.

Fig. 478.
BIRD'S OVARY (Carus.)

The calyces composing the ovary are in various stages of development, a few being nearly ripe, but the greater number minute and in a comparatively backward state. Their dehiscence and the expulsion of the eggs therefore takes place one by one, in regular succession, a certain interval intervening between the escape of the eggs.

1061. **The Calyx** is a hollow spheroidal case surrounded by several layers of blood-vessels, lymphatics, and nerves, connected together by cellular tissue and peritoneum. The blood-vessels on the external surface are composed of two layers, the exterior consisting of vessels of large calibre, and the interior of a much smaller reticulation. The inner or concave surface is tufted over with a vascular villosity, in which the germ of the egg is produced by the process of secretion, and in which the veins predominate greatly over the arteries as well in magnitude as in number.

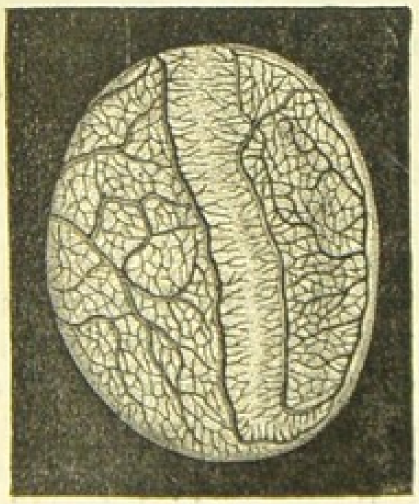


Fig. 479.
CALYX FULLY DEVELOPED, SHOWING THE SURROUNDING BLOOD-VESSELS AND THE STIGMA (Baudrimont and Martin St. Ange).

As the calyx enlarges, its vascular activity undergoes a rapid increase, all the vital energy of the ovary appearing to be, for the moment, concentrated in those calyces which are about to deliver their eggs to the oviduct, those in the more backward state being temporarily inert. This concentration of the formative activity, producing gradations of development in the egg, is in accordance with the functions of the animal. If several calyces ripened and enlarged together, the ovary would attain undue and injurious magnitude, and the eggs would be discharged into the oviduct in such rapid succession, that that organ would be incapable of secreting the accessory parts which it is its function to supply. The secreting powers therefore of the ovary and

the oviduct are nicely adapted each to the other, egg after egg being evolved in the one at such intervals as enables the other to supply the albumen, the membranes, and the shell.

When the calyx is in a state of full development and ready to expel the egg, the ovary and the numerous blood-vessels which interlace its sides acquire an enormous volume.

A slightly magnified view of the calyx is shown in fig. 480, and one is represented in fig. 479 in its natural magnitude after the discharge of the egg.

1062. **The Stigma.**—Their ramifications cover the entire surface, except a semicircular band extending over that part along which the fissure is subsequently produced through which the egg is expelled. It will be seen by the figure that the limit of the visible blood-vessels is distinctly traced in two parallel directions along the edges of this zone, which is called the *stigma*. Until recently it was maintained by physiologists that this stigma is not vascular. Messrs. Baudrimont and Martin Saint-Ange,* however, have shown that this is not strictly true, for although the stigma is divested of the larger class of blood-vessels, it is nevertheless the seat of minute capillaries.

Fig. 480.

1063. **The Egg**, when first formed in the ovary, appears under the form of a minute semi-transparent vesicle, proved by these physiologists to be produced, not as hitherto supposed by a sort of budding or exfoliation, but by a process of true secretion. As it enlarges within the calyx, the vitellus or yolk collects round it, enclosed by the vitelline membrane. In the midst of the yolk the germinal vesicle, including the germ, is formed. The germinal vesicle is placed in the centre of the whitish spot which constitutes the cicatricula.

When dismissed from the calyx, and discharged into the oviduct, the egg, therefore, consists of the vitelline membrane, enclosing the yolk, within which is the germinal vesicle, enclosing within it the proliferous disc and the germ.

1064. **Chalazæ.**—On entering the oviduct, the egg thus constituted becomes fecundated and encounters the albumen in

* Mem. Acad. Sc. Tom. XI.

abundant quantity secreted by that tube. This collecting round the yolk, is condensed upon it, and formed into a layer, which applies itself in immediate contact with the vitelline membrane. The egg, as it advances through the oviduct, is endowed with a rotatory motion around its axis, by means of which the albuminous envelope just described is twisted at both ends, just as a towel would be when water is wrung from it. By these means, those twisted parts of the albuminous coat which extend beyond the vitelline mass, form those appendages called the *chalazæ*. The albuminous membrane here described has on this account received the name of the *membrane of the chalazæ*.

1065. **Membrane of Albumen.**—In its further progress, the egg collecting round it an increased quantity of albumen, that substance becomes condensed upon it in contact with the membrane of the chalazæ, and another membrane is formed on the exterior of this condensed albumen, consisting of a fine transparent pellicle, called the *membrane of the albumen*.

1066. **Membranes of the Air-Chamber.**—As it continues its further progress through the oviduct, it receives a fresh accession of albumen, which is now fluid and less condensed. Upon this fluid albumen is formed a double membrane, called, for a reason which will presently appear, *the internal and external membranes of the air-chamber*. These membranes, therefore, contain, in a closed sac, all the previously formed parts of the egg.

1067. **Isthmus.**—The egg in this state arrives at a point of the oviduct called the *isthmus*, where the secreting organ of the albumen terminates ; after passing which, it enters a lower part of the oviduct, in which a calcareous secretion takes place, by which the materials of the shell are deposited upon the external membrane of the air-chamber just described. This deposit immediately solidifies, and the shell is constituted.

1068. **Epidermoid Membrane.**—Then comes a last secretion of another order, by which a superficial membrane, called, from its analogy to the epidermis, the *epidermoid membrane*, is formed upon the external surface of the shell. The material of this last secretion contains a colouring matter which varies with the species of the bird, and gives to the egg its characteristic colour, whether uniform, varied, or spotted.

1069. **Theoretical Section of Egg.**—The constitution of the egg here described will be rendered more clearly intelligible by the theoretical section (fig. 481), where the parts above described are indicated as follows :

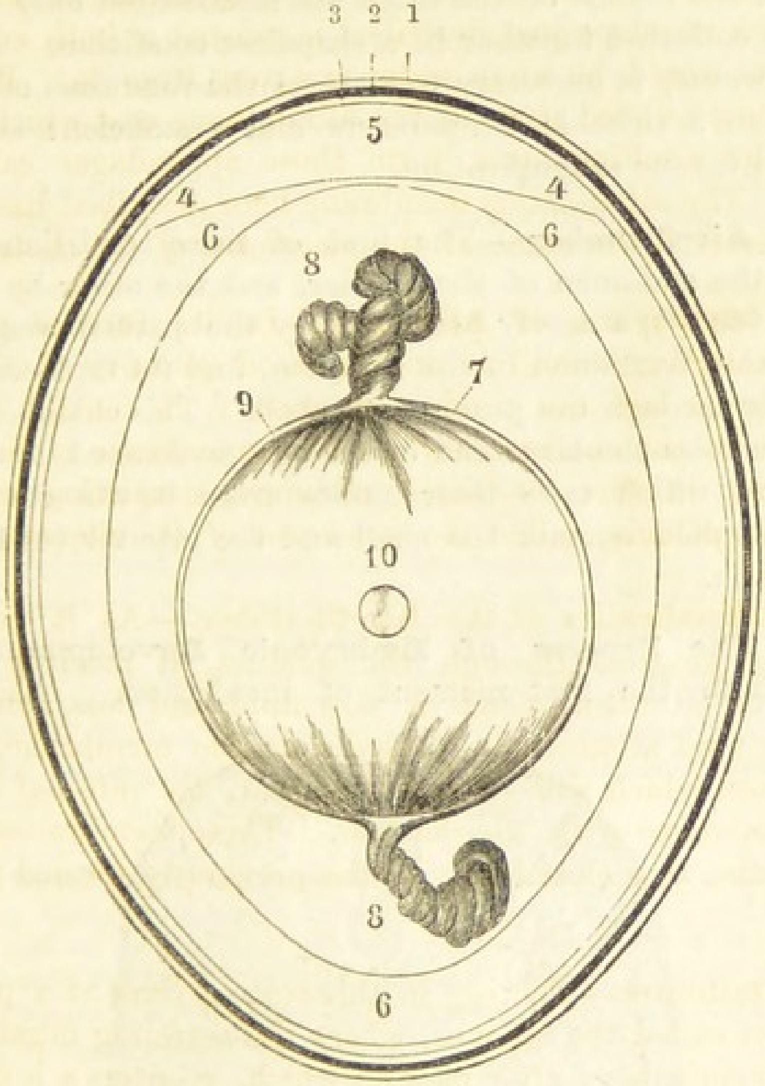


Fig. 481.

THEORETICAL SECTION OF THE HEN'S EGG (Baudrimont and Martin St. Ange).

1. Epidermoid membrane of the shell. 2. The shell. 3. External membrane of the air chamber, applied immediately upon the internal surface of the shell. 4, 4. The internal membrane of the air chamber applied upon the inner surface of the preceding membrane everywhere except at the large end of the egg. 5. The air-chamber. 6, 6, 6. The membrane of the condensed albumen. Between this membrane and the internal membrane of the air-chamber the liquid albumen is included. 7. The membrane of the chalazæ. Between this and 6, 6, 6, the condensed albumen is included. 8, 8. The chalazæ twisted at the ends, as already described. 9. The vitelline membrane. 10. The germinal membrane, *blastoderma* or *cicatricula*, a small flat disk in which the rudiments of the embryo afterwards begin, and which probably receives the contents of the germinal vesicle, now ruptured.

1070. While the formation of the accessories of the egg is

in progress in the oviduct, its essential parts are modified. The germinal vesicle visible at first has disappeared, being broken, and its contents diffused in the concavity of the *blastoderma*, or germinal membrane or disc, fig. 481[10]. At this point the organs of the chick are represented only by their materials collected together in a shapeless condition. Nothing more, however, is necessary to awaken the functions of assimilation than a suitable temperature and a sufficient supply of oxygen to favour sanguification.

1071. **Air-Chamber.**—The first of these conditions is fulfilled by the abdomen of the mother, and the other by the air-chamber (481[5]), a cavity produced by the partial evaporation of the water contained in the albumen, and its replacement by air passing through the pores of the shell. This chamber, which always occupies the large end of the egg, is limited by the two membranes which take their names from it, the exterior of which is applied against the shell and the interior (481[4]) upon the albumen.

1072. **The Process of Embryonic Development** commences from the first moment of incubation. About the

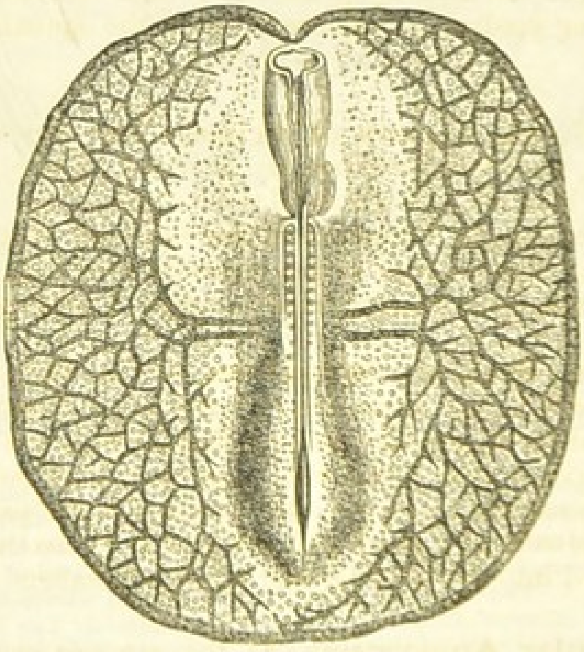


Fig. 482.

TRANSPARENT AND VASCULAR AREA ABOUT THE 37TH HOUR OF INCUBATION (Baudrimont and Martin St. Ange).

sixth hour the blastoderma or germinal disc is raised above the mass of the yolk. Three hours later it becomes opaque,

and its volume rapidly increases. Having at first no more than the eighth of an inch in diameter, it acquires at the end of twelve hours a diameter of half an inch.

Fecundation having impressed a vital movement on the globules or cells accumulated in the disc, these arrange themselves in such a manner as to form two distinct regions, one peripheric, and called the *opaque area*, and the other diametral, and named the *transparent area* (fig. 482).

The transparent area is represented here lying along the diameter of the vascular area. Along the centre of the transparent area appears the double encephalic cord, already flanked by the rudiments of the vertebræ, and upon the sides a multitude of fine vitelline granulations are collected, which are crowded one against the other, prepared to undergo the metamorphoses destined to convert them into the organs of the young animal.

The globules of the blood put in motion by the cardiac vessel mark out the vascular area pressing aside the fatty vesicles contained between the laminæ of the blastoderm. It is not until a later epoch of the development that the motion of these globules is limited by vascular tubes.

1073. **Vertebral Column.**—At the beginning of the second day of incubation part of the formative molecules group themselves to organise the vertebral column, and two parallel rows of square spots are formed, separated one from the other by a pellucid line. These are destined ultimately to unite, two and two, on the internal sides, to form the bodies of the vertebræ. The line separating the two rows is occupied by a transparent fluid which, being gradually condensed, forms the spinal marrow and the brain.

1074. **Skull and Organs of Sense.**—The cerebro-spinal axis is soon after bent, the cephalic extremity inclining forward, and it is at that moment that on both sides of the skull the cavities of the orbits are formed, in which are subsequently accumulated the humours destined to form the organs of vision. Next appear at the posterior part two other depressions prepared to receive the rudiments of the organs of hearing.

1075. **Bones—Muscles—Members.** — The first formation of the bones is announced by the appearance of cartilages destined eventually to become hardened by calcareous matter. The muscles are at first developed in the dorsal region ; after which two pairs of stumps make their appearance, one at the superior, and the other at the inferior part of the embryo. These being gradually elongated and subdivided by articulations, are ultimately converted into the superior and inferior members of the animal.

1076. **Vascular Apparatus.**—At the commencement of the third day the vascular system has not yet been manifested. The whole surface of the transparent area (fig. 482) appears granular. These granulations represent innumerable transparent globules, which also abound in the opaque area, where they are mixed with oily vesicles. These globules and oily vesicles are enclosed in a double lamina, within which the blood is formed. The blood appears first in the form of spherical corpuscles,

slightly coloured and a little opaque at the centre. These soon after assume the forms of elliptical globules of a bright red colour, with a central nucleus.

According as these blood corpuscles multiply, the oily vesicles and granules diminish in number, which leads to the probable supposition that the latter enter into the composition of the former. It is about the fiftieth hour of the incubation that the blood corpuscles become distinctly visible. If the disc be then observed, it will be found that all the globules are agitated by a regular motion, and seem to force their way among the oily vesicles. It is evident that the blood-vessels, properly so called, are not yet formed. The blood therefore, at first, makes for itself a path in the tissues, and it is not until a later period that the system of vascular canals is formed, by which it is guided in its motion.

1077. **The Circulation of the Embryo of the Chick,** like that of the mammifer, undergoes a series of changes with the progress of organic development. These changes consist of four phases, which have been denominated severally the *primitive circulation of the vitellus*, the *permanent circulation of the vitellus*, the *circulation of the allantois*, and the *definitive circulation of the chick.*

1078. **The Primitive Vitelline Circulation,** the duration of which is two days, takes place in a part of the germinal membrane called the *vascular area*, which with the rudiments of the heart of the chick and its cardiac vessels in the centre, is represented in fig. 485, with a diameter magnified about six times. The arteries are distinguished from the veins by a lighter shading.

1079. The large vessel V P, by which the vascular area is surrounded, is called the *primigenial vein.* Externally it has no branches, but is connected with the network within by innumerable ramifications. Its course around the area is somewhat irregular, throwing in at certain points re-entrant angles, and at others contracting its calibre, so as to form a comparatively narrow neck. At a point corresponding with the position of the cephalic extremity of the embryo it turns inwards with a deep and very acute re-entrant angle, at the vertex of which the converging points coalesce so as to form a single trunk, which is continued to the heart, which it enters at an enlargement of that organ, to which MM. Baudrimont and Martin St. Ange have given the name of *subcardiac vessel.*

1080. At a part of the vascular area diametrically opposite to that from which this trunk comes, another large venous trunk (V C), called the *caudal vein*, proceeds and enters the heart at the same point.

Both of these trunks communicate with the surrounding vessels by numerous ramifications.

Two other venous trunks of still larger calibre enter the heart at the sides, a fifth receives branches, proceeding from the body of the embryo. The motion of the blood in all these five trunks directed from the borders

of the area to the heart was distinctly seen by the observers already cited.

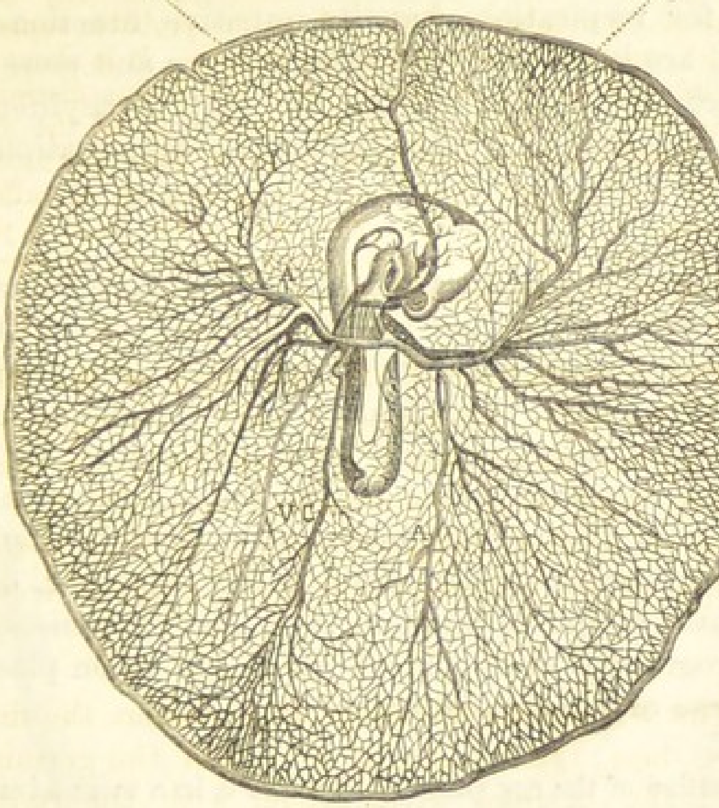


Fig. 483.

VASCULAR AREA, SHOWING THE PRIMITIVE CIRCULATION OF THE VITELLUS (Baudrimont and Martin St. Ange).

The venous blood flowing from these trunks into the subcardiac vessel, which may be regarded as the analogue of the portal vein, is discharged into a curved vessel susceptible of a regular rythmical contraction, and which is the rudimentary heart.

1081. The heart which has thus received the venous blood coming from the circumference to the centre pushes, in its turn, the blood through the arteries from the centre to the circumference. The vascular area, which is the theatre of this primitive circulation, may be regarded as a sort of lung formed above the embryo, and placed under the air-chamber, where the oxygen can enter it most easily. This constitutes a simple pulmonary circulation analogous to that of fishes, the duration of which is about two days.

1082. The primitive vitelline circulation described above is terminated by the ramifications of the arterial and venous vessels, which run parallel to each other between the centre of the vascular area and the primigenial vein, anastomosing ; in consequence of which the primigenial and caudal veins, receiving an insufficient supply of blood, soon atrophise and wither.

1083. **The Second Circulation** then commences. The vascular area, deprived of its principal venous trunks, and ceasing to communicate so fully as before with the air-chamber, becomes less fitted for respiration, but its nutritive functions, on the other hand, are improved. It spreads more and more over the yolk, whence, its vessels playing the part of chylifers, derive abundant materials for the increasing organisation of the embryo.

1084. **Allantois.**—Meanwhile the pulmonary functions are transferred to another and different apparatus. According as the vascular area loses its primigenial and caudal veins and their tributaries, the allantois appears, and is converted into a new respiratory organ, eminently suited by its connection with the embryo to favour the development of the interior parts of the animal, hitherto retarded by the peculiar nature of the primitive circulation. Before, however, describing this new phase of the circulation, it will be convenient to illustrate the progressive development which has taken place during the first phase of the circulation.

1085. A section of the egg shown in fig. 484 is in a more advanced stage than that already shown in fig. 481.

In this figure is seen one of the chalazæ, 8, the other being hidden on the opposite side of the egg. 11′ is the cicatricula upon which the vascular area is spread. 9′ is the internal granular layer of the vitelline membrane which some physiologists have, erroneously, according to Messrs. Baudrimont and Martin St. Ange considered as constituting a part of the blastoderm, out of which the embryo is formed.

In fig. 487 is represented a theoretical section of the egg, showing the embryo in a stage of still further development. In this case 11′ is the germ more developed, bulging up the vitelline membrane. 11, 11 is the primigenial vein included between the two laminæ of the germinal membrane and extending itself more and more under the vitelline membrane in the place of the granular layer which lines the latter. The membrane of the chalazæ is raised by the embryo as well as the vitelline membrane, of which, however, it does not exactly follow the contour.

A section of the egg illustrating a still more advanced stage of the development of the embryo is shown in fig. 486.

11′ is the embryo beginning to assume a distinct form. 11, 11 are the folds of the membrane about to form the cephalic and caudal hoods.

About the end of the third day of the incubation the allantois begins to be developed from the abdominal region of the embryo. The state of the egg at this period is illustrated in fig. 487.

The parts numbered from 1 to 10 are the same as those in fig. 481. One only of the chalazæ (8) appears, the other being on the opposite side. 9, 9′. Internal granular layer of the vitelline membrane. 10. The embryo beginning to be developed and depressing the yolk. 11. The primigenial

vein, already atrophised, limiting the vascular area, which extends itself more and more in the place of the granular stratum of the vitellus. 13. Folds of the cephalic and caudal hoods approaching each other, the space

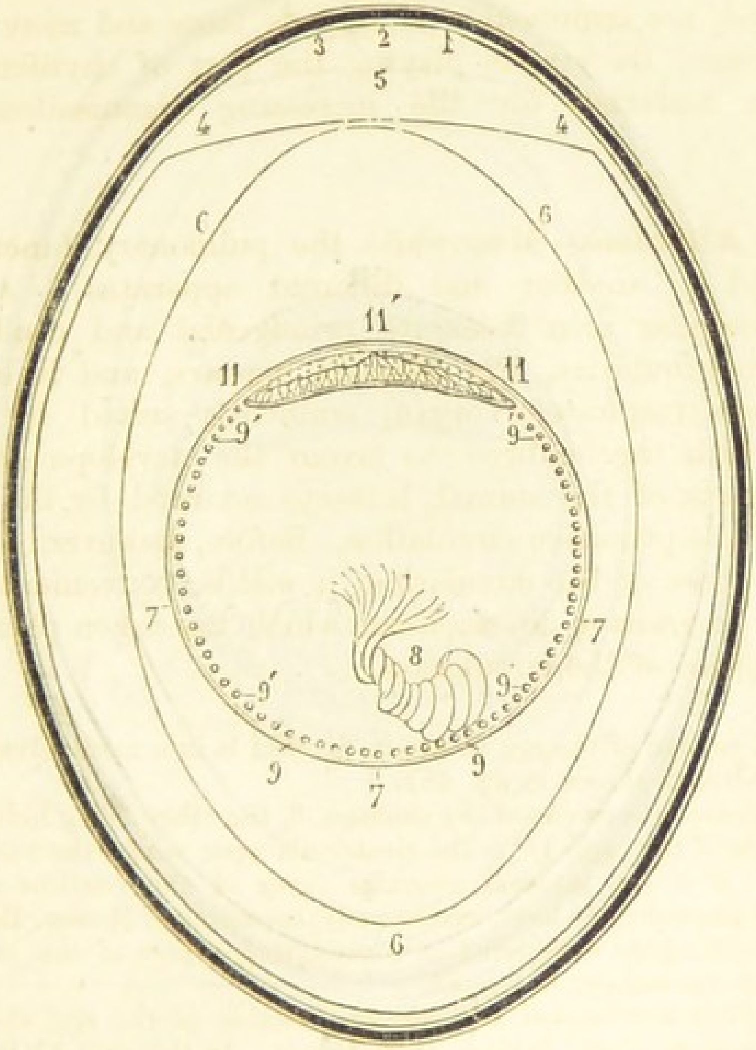


Fig. 484.

THEORETICAL SECTION OF THE HEN'S EGG IN THE SECOND STAGE OF DEVELOPMENT (Baudrimont and Martin St. Ange).

between them being the umbilical opening of the amnion, which, however, very soon disappears when the development of the embryo progresses. 15, 15. The cavity of the amnion. 14. The pedicle of the allantois, corresponding to the cloaca. The allantois makes its appearance at the moment of the metamorphosis of the vascular area. It supplies the place of the vitelline organ whose respiratory function gradually ceases with the disappearance of the primigenial cephalic and caudal veins.

The next stage of the development is shown in fig. 488.

1 to 9. The same parts as in the former figures.

10. The embryo in a more developed state. The primogenial vein no longer exists. The vitelline veins and artery have arrived at the limit of their development, and constitute the vitelline circle 16.

12, 12. Folds of the vitelline membrane which form the cephalic and caudal hoods.

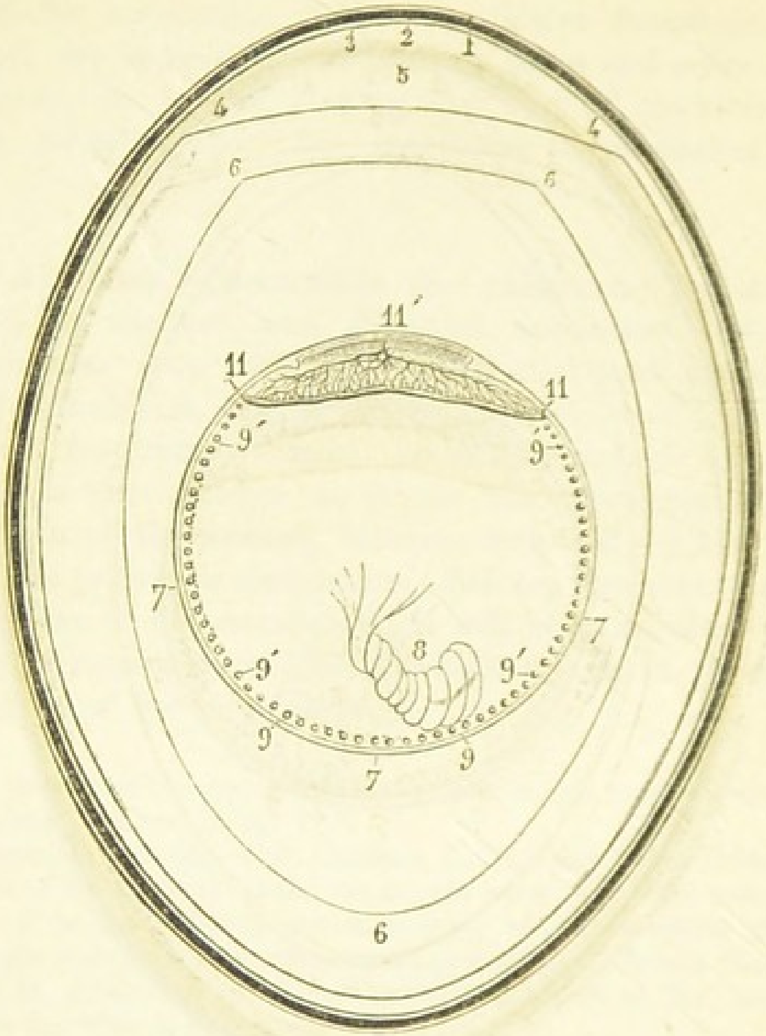


Fig. 485.

THEORETICAL SECTION OF THE HEN'S EGG IN THE THIRD STAGE OF DEVELOPMENT (Baudrimont and Martin St. Ange).

15, 15. Cavity of the amnion, which is more and more enlarged by the gradual accumulation of the serous transparent fluid called amniotic liquid.

14. The allantois commencing its development and pushing before it the vitelline and chalazean membranes.

16. The vitelline circle.

1086. From the fifth to the sixth day the allantois covers the little embryo, and circumscribes all the parts included in the internal membrane of the air-chamber. About the tenth day it has already surrounded and embraced the whole of the vitellus, the embryo, and the albumen. From the twelfth to the

thirteenth day the junction of the allantois has taken place at the small end of the egg. Its external fold, which lies against

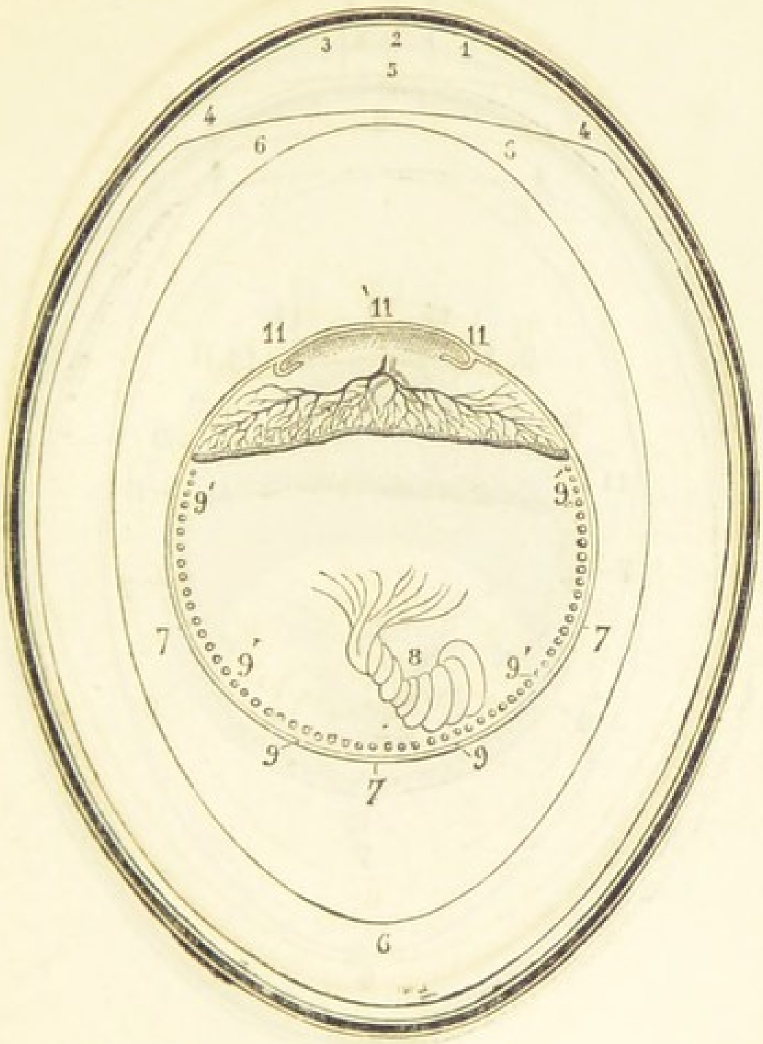


Fig. 486.

THEORETICAL SECTION OF HEN'S EGG IN THE FOURTH STAGE OF DEVELOPMENT (Baudrimont and Martin St. Ange).

the internal membrane of the air-chamber until the chick breaks the shell, is covered with a magnificent vascular system, which receives the venous blood coming from the embryo, and puts it in contact with the air to arterialise it.

1087. About the eleventh day the state of the embryo and the parts of the egg surrounding it is as shown in the section, fig. 489.

10. Embryo raised upon its side to show the umbilical cord composed of the vitelline vessels and the pedicle of allantois.

13. Point of suture at the sides of the amnion formed by a fold of the vitelline membrane.

14. The allantois highly developed, having driven back in all directions

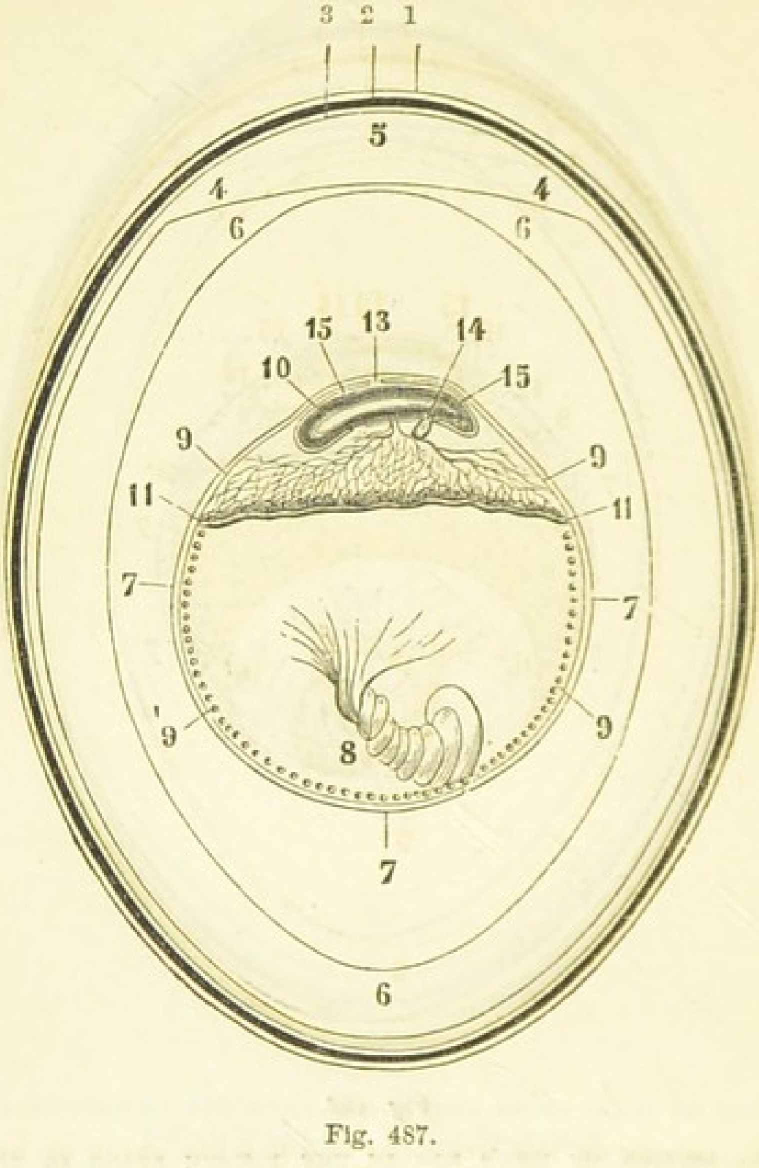


Fig. 487.

THEORETICAL SECTION OF THE HEN'S EGG IN THE FIFTH STAGE OF DEVELOPMENT (Baudrimont and Martin St. Ange).

around it the vitelline and chalazean membranes, as well as the membrane of the external albumen so as to apply itself upon the internal surface of the shell, and thus put itself into immediate contact with the porosity of the latter, and to receive the oxygen of the external air and arterialise the blood circulating in its vessels.

15. The cavity of the amnion much enlarged by the accumulation of the amniotic liquid. At the base of the section is seen the point where the junction of the allantois takes place, so as to include in its vascular fold the condensed albumen which remained at the small end of the egg. All the parts of the egg, with the exception of the membranes of the air-chamber and the shell, are thus included on the thirteenth day of the incubation in a close sac.

1088. The allantois being developed within the vitelline membrane, it cannot force its way outwards towards the shell,

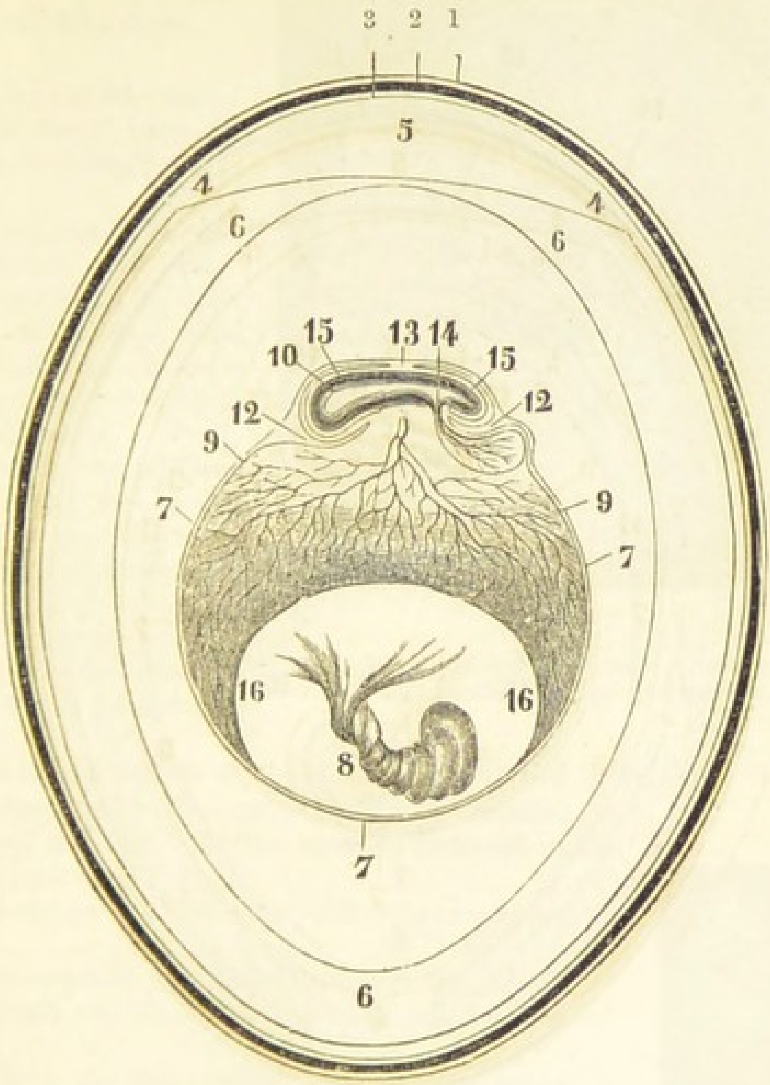


Fig. 488.

THEORETICAL SECTION OF THE HEN'S EGG IN THE SIXTH STAGE OF DEVELOPMENT (Baudrimont and Martin St. Ange).

as shown in fig. 489, without pushing before it the vitelline membrane, as well as the membranes of the chalazæ and the condensed albumen, which lie outside the latter. This succession of membranes, proceeding from the vitellus outwards, appear overlying each other on the internal surface of the shell in the theoretical section (fig. 489). It would nevertheless be a great error to assume that they actually co-exist as a multiple lining of the shell at any epoch of the development. At the commencement of the period of incubation, the vitelline membrane is extended over the amnion and the allantois, the

membrane of the chalazæ being then superposed upon it, but distinct from it. But at a later epoch, it is impossible to

Fig. 489.

THEORETICAL SECTION OF THE HEN'S EGG IN THE SEVENTH STAGE OF DEVELOPMENT (Baudrimont and Martin St. Ange).

distinguish them, or rather, the inner membrane alone remains, that of the chalazæ having disappeared by atrophy. In fine, membrane after membrane disappears, proceeding thus from without inwards, each inner membrane assuming the function of that which ceases to exist.

1089. Before we resume the exposition of the phenomena of the circulation, it will be useful to reproduce some of the figures drawn by M. Martin Saint Ange, showing with the greatest precision and in their natural dimensions the condition

of the embryo and its accessories at some of the stages of development illustrated in the preceding theoretical diagrams.

The embryo at the middle of the fourth day of incubation is shown in fig. 490.

It is supposed to be viewed from the side which corresponds to the yolk, to show the distribution of the blood-vessels and the relation with the allantois.

Its state in the middle of the fifth day is shown in fig. 491, the origin of the allantoid vessels appearing.

In all cases the veins are indicated by black, and the arteries by dotted lines.

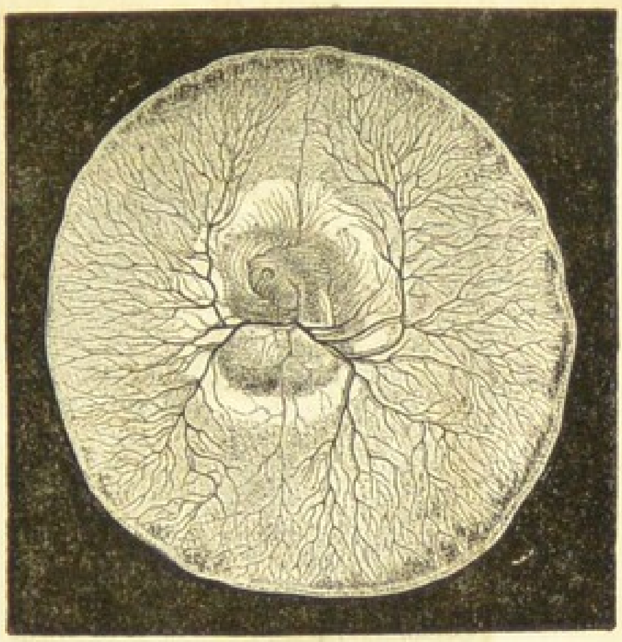


Fig. 490.

EMBRYO OF THE CHICK ON THE FOURTH DAY OF INCUBATION (Baudrimont and Martin St. Ange).

Its state in the middle of the sixth day is shown in fig. 492.

In this drawing the embryo is shown in relation to the allantoid and the vitelline vessels, disposed in the form of a lyre.

The embryo on the sixth day of incubation is shown in fig. 493.

The membrane of the chalazæ is here cut to render more distinctly visible the position and relations of the allantois.

The embryo on the seventh day of incubation is shown in fig. 494.

The relations of the embryo to the yolk and the membranes which envelope it are here shown.

Fig. 491.

a. The membrane of the chalazæ disengaged from above the chick.
b. The vitellus and vitelline membrane which covers the vascular lamina of the blastoderm.
c. The amniotic sac scarcely raised by the liquid it contains.
d. The vascular allantois isolated and folded, attached by its pedicle to the cloaca of the chick.

1090. To resume the exposition of the successive phases of the circulation, we shall take the state of the circulatory apparatus of the chick on the fifteenth day of incubation, when the allantoidal and vitelline vascular systems are in a state of nearly equal activity, as is proved by the nearly equal calibre of their principal vessels.

To illustrate this rather complicated system we shall avail ourselves of

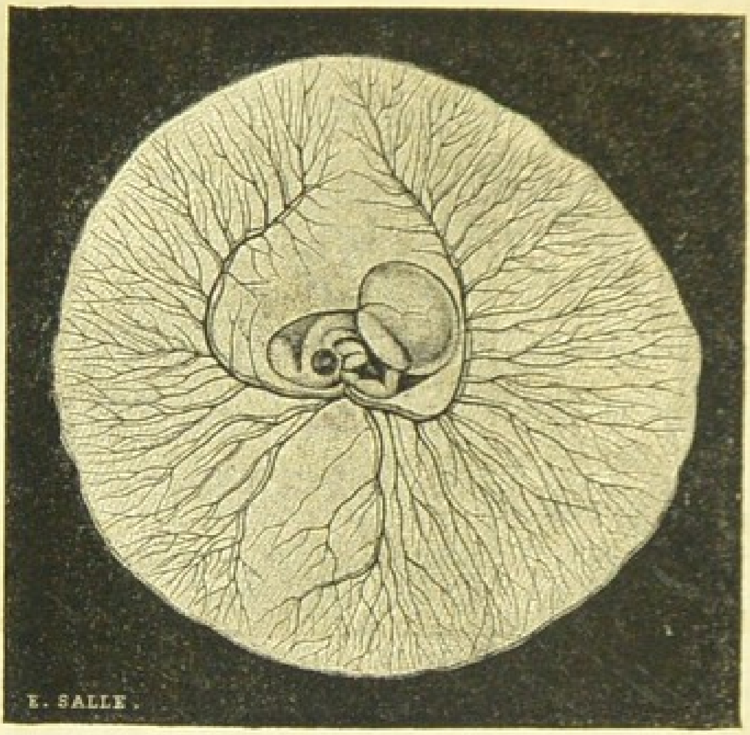


Fig. 492.

EMBRYO OF THE CHICK AFTER FIVE AND A HALF DAYS' INCUBATION (Baudrimont and Martin St. Ange).

the drawing reproduced in fig. 495-6 from that of M. Martin Saint Ange, made from nature with the most elaborate precision, representing the

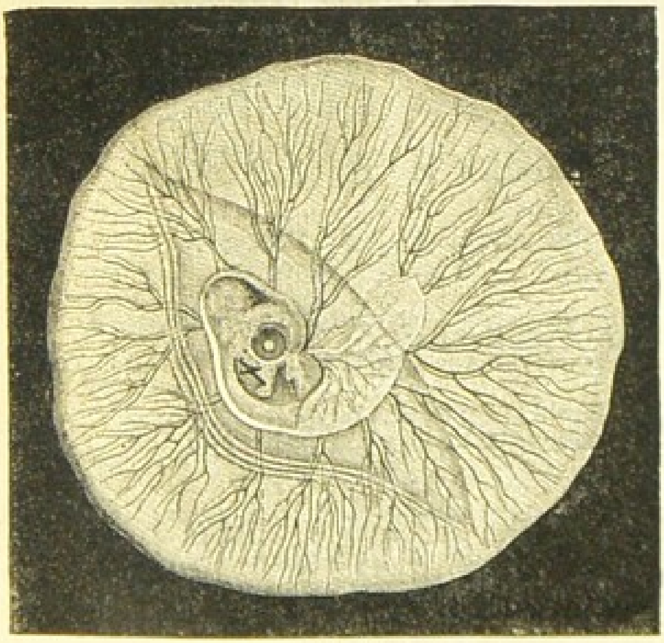


Fig. 493.

EMBRYO OF THE CHICK, SIX DAYS' INCUBATION (Baudrimont and Martin St. Ange).

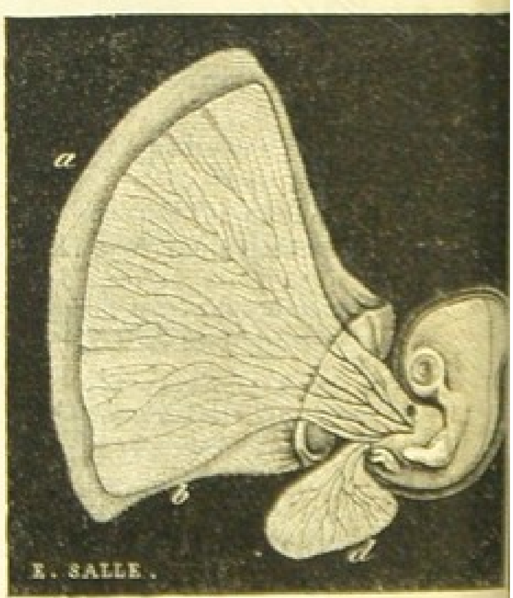


Fig. 494.

EMBRYO ON THE SEVENTH DAY OF [IN]CUBATION (Baudrimont and Mar[tin] St. Ange).

blood-vessels, intestines, and other organs of the chick at the epoch just mentioned.

In fig. 496, the heart and the vessels which more immediately issue from it are represented separately to render them more distinct. The following are the principal parts shown in the figures.

In fig. 495 *a* is the allantois. *b*. The vitellus or yolk. *c*. The condensed albumen. *d*. The embouchure of the cloaca. *e*. The pouch of Fabricius. *f*. The reproductive organs. *g*. The stomach. *h*. The pedicle which forms a communication between a loop of the intestine and the vascular pouch of the vitellus. *i*. The spleen.

The different classes of blood-vessels are distinguished each by a peculiar shading. The arteries which carry the mixed blood from the heart are shaded thus . The veins proceeding from the cephalic, œsophageal, caudal, hepatic, renal, spermatic, and Fabrician organs, all of which are traversed by venous blood, are thus marked . The great vein proceeding from the allantois which carries the arterialised blood back to the heart is thus marked ; and, in fine, the portal vein which brings back to the heart the blood from the vitellus and other vessels is thus marked .

In fig. 496, which shows the vessels immediately issuing from the heart divested of the surrounding parts, *b* is the right ventricle of the heart, *c* the left arterial canal, *d* the right arterial canal, these two vessels being the analogues of the two arterial arches of reptiles. *e* is the permanent arch of the aorta, and *f* the descending aorta in which the three vessels *c*, *d*, and *e* coalesce. The two small branches marked *a a*, which issue right and left from the arterial canals, are the rudiments of the future pulmonary arteries. On issuing from the heart the arch of the aorta (496 *e*) gives out the two subclavian arteries (495 *r*), after which it receives the right and left arterial canals (496 *c*, *d*). After the junction of these several branches proceeding from the right cavity of the heart, the descending aorta throws off, at 495 *q*, a branch towards the lumbar region, which goes to the liver, the stomach *g*, the spleen *i*, and the duodenal and cæcal parts of the intestine. A little lower, the aorta bifurcates, dividing into two principal trunks, *t t′*, the calibre of the right *t* being a little greater than that of the left *t′*. The left trunk *t′* proceeds at first without giving off any branch, but lower down it sends off little arteries at the intestinal portion situated below the duodenum. After having thus furnished ramifications to the alimentary canal it bifurcates at *l*, the two branches bestriding a loop *u* of the intestine, and including between them the pedicle *h*, which connects the same loop with the vitellus, this pedicle having a decreasing calibre from the intestine to the vitellus.

The two branches of the artery arriving at the vitellus diffuse themselves over it so as to form the vitelline circle against which the condensed albumen *c* is applied. This left trunk of the principal bifurcation of the aorta of the chick is designated the omphalo-mesenteric, or vitelline artery.

The right trunk *t* of the chief bifurcation of the descending aorta sends out lateral branches to the organs of the pelvis, and then again bifurcates at *m*, forming the primitive iliacs, and is continued to the caudal extremity under the name of the middle sacral artery. Of the two primitive iliacs the right sends out the crural artery and a branch which, arriving upon the allantois at *n*, forms a remarkable plexus, from which issue fine ramifications which follow the course of some veins of the allantois.

The left iliac supplies, immediately below the bifurcation *m*, the crural artery of the left side, and a considerable branch *o*, which may be regarded as the continuation of the aorta, and which, arriving upon the allantois, spreads itself over it by innumerable ramifications. The two arteries which are thus diffused upon the allantois, and proceed from the primitive iliacs, are evidently the analogues of the umbilical arteries of mammifers, with this difference, however, that the right, much smaller than the left, is, in the case of the chick, altogether rudimentary at the close of the period of incubation.

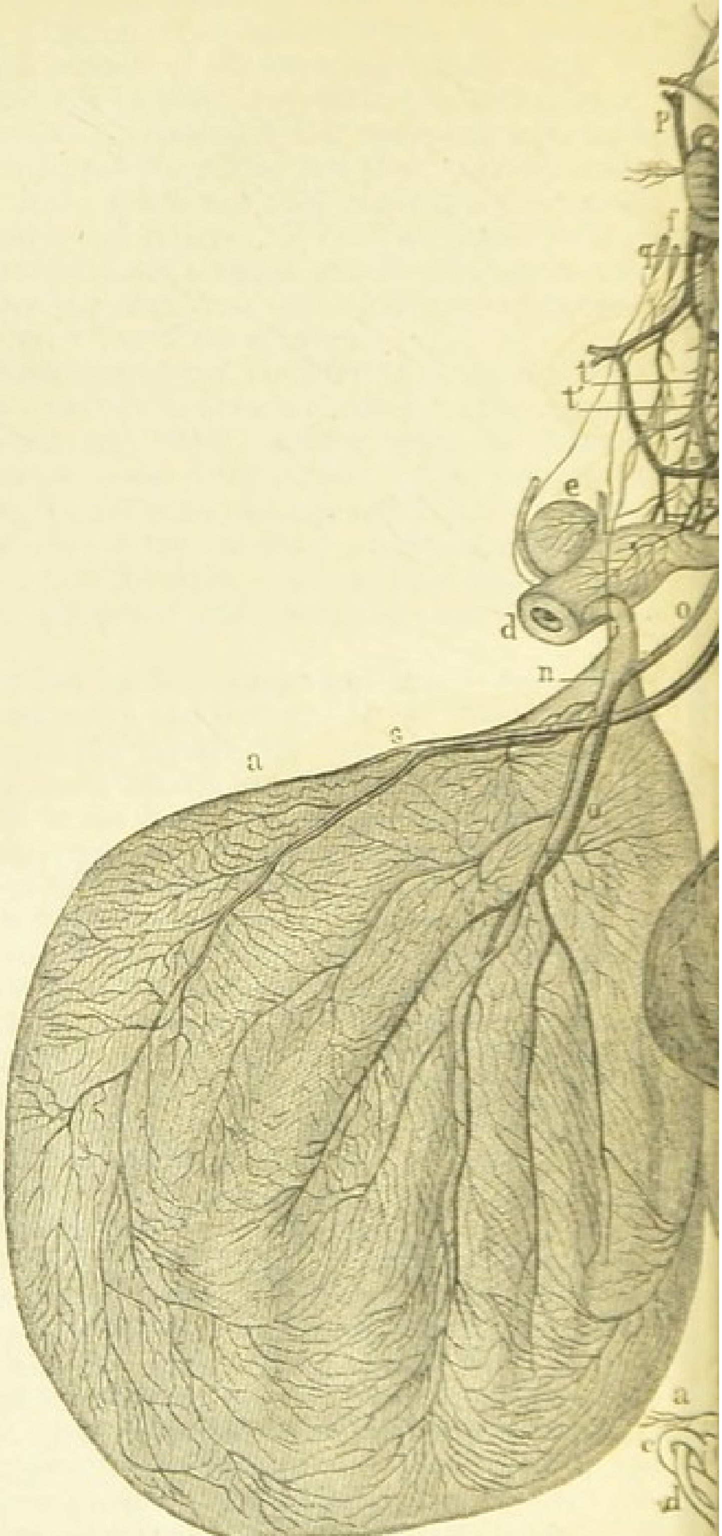
The principal veins are called by Baudrimont and Martin Saint Ange, the permanent veins, the vena portæ, and the veins of the allantois.

The permanent veins include the jugular, the venæ cavæ, the hepatic, the renal, and so on. The most remarkable peculiarity attending the venous system of the chick is the very large anastomose which exists between the permanent venous system and the vena portæ. This communication is placed at the point the most remote from the pelvis, where the two trunks which leave the crurals turn inwards, and unite in an arch before reaching the caudal region. Thus, the trunk of the inferior cava, *q*, bifurcates near the division of the aorta, forming a right and left trunk. Each of these trunks sends a branch to the organs of reproduction, and one to the corresponding kidney, and then gives off the crural vein, after which it bends at right angles, preserving its calibre ; follows the hinder part of the kidney, sends a little trunk into the caudal region, which is distributed over the pouch of Fabricius ; and, in fine, unites in an arcade with the other trunk. It is at this point, *x*, that it anastomoses with a large branch of the vena portæ.

The system of the vena portæ in adult animals generally includes all the veins which proceed from the stomach and intestinal canal, the pancreas, and the spleen. In birds, the anastomosing trunk which proceeds from the inferior vena cava must be added to these. Besides these, we find in the chick of fifteen days' incubation a large branch *k*, which comes from the vitelline veins, and which constitutes at this epoch of embryonic development the most important vessel of the entire system of the vena portæ. This branch *k*, and the vitelline artery which accompanies it, are the analogues of the omphalo-mesenteric vessels which are distributed over the umbilical vesicle of mammifers. The common trunk of the vena portæ, after this, throws itself into the liver, anastomoses with the hepatic veins, and through them reaches the right auricle of the heart. This common trunk of the vena portæ is that which corresponds at the commencement of the incubation with the subcardiac enlargement of the heart already mentioned in our explanation of the first and second vitelline circulations.

The trunk of the principal vein of the allantois is by far the most volu-

Fig



Fi

GENERAL CIRCULATION OF THE CH

THE 15TH DAY OF INCUBATION.

[To face page 675.]

minous of all the vessels of the embryo. It constitutes by its numerous ramifications a magnificent network of feathered veins, in immediate connection with the last division of the arteries. At its entrance into the abdomen, the umbilical vein passes upon the left side of the intestines, surrounds the duodenum, and opens *directly* into the right sub-auricular cavity. This umbilical vein *supplies no branch* whatever along its course from the umbilical point to the heart—an anatomical fact of great importance in the general circulation of the chick of fifteen days' incubation.

This termination of the venous trunk differs from that observed in the embryo of mammifers, inasmuch as in the latter the principal trunk of the umbilical vein opens into the system of the vena portæ, after having furnished the venous canal and numerous branches to the left lobe of the liver. Therefore, the considerable anastomosis, which in mammifers leads from the umbilical vein to the vena portæ, is completely absent in the chick.

1091. Here terminates the anatomical description of the vessels, arterial and venous, distributed upon the organs, permanent and transitory, of the embryo chick at the fifteenth day of incubation. It is easy to perceive that the calibre of all these vessels, being connected with and dependent on the different organic functions of the embryo, must vary according as these functions languish or disappear. Thus the primigenial vein is effaced when the vessels of the allantois are developed. The omphalo-mesenteric vessels atrophise in part after the formation of the intestinal tube, and the remaining vessels disappear with the organ whose function ceases. It is the same with the umbilical vein, which atrophises suddenly from the nineteenth to the twenty-first day of incubation, consisting at the moment of birth of no more than a small withered and obliterated vessel.

This atrophy of the umbilical vein is not produced in the same manner as in mammifers, because, in the latter, the function of pulmonary respiration commences only at the moment of birth, while the embryo chick respires free air, being still in the shell. Thus it appears that the phases of the circulation are always subordinated to the successive changes of function.

1092. During the first vitelline circulation, the blood propelled through the aorta passes almost exclusively into the vascular area, the carotid and middle sacral arteries being still in the rudimentary state. This blood passes into the entire vascular net-work of the vitelline area, then into the primigenial, caudal, and lateral veins which pour it into the subcardiac cavity already mentioned. This latter cavity also receives the other small veins of the body, and the venous

blood thus returns to the heart to be again propelled into the vascular area. It appears, therefore, that the blood which circulates through the vessels of this first vitelline circulation can only receive its respirable elements in the capillaries of the vascular area which are, as already stated, in contact with the air-chamber. According as the blood of the lateral arteries passes more freely into the adjacent veins, the primigenial and caudal veins disappear by degrees.

1093. As the former circulation was analogous to that of fishes, the present represents exactly that of amphibia, since the heart receives arterial blood by the lateral veins, and venous blood by means of the venæ cavæ ; a mixture taking place, therefore, before the next distribution of blood into the arteries.

This second or permanent vitelline circulation begins to be modified as soon as the formation of the alimentary canal is completed. Then the common trunk of the vitelline artery, which hitherto greatly exceeded in volume the abdominal aorta, loses its advantage over the latter. A greater quantity of blood passes through the umbilical arteries, from whence it returns *directly* to the right sub-auricular enlargement or cavity. There it is mixed with the blood proceeding from the hepatic veins, and the inferior cava, *q*, and then arrives thus mixed in the right auricle, where it encounters the blood which is poured in there by the coronary veins and the superior cavæ. The contraction of this right auricle propels the blood partly into the right ventricle, and partly into the left auricle. The former current is driven by the contraction of the ventricle into the pulmonary trunk (fig. 496 *b*). A small portion of this is sent to the lungs by the rudimentary pulmonary arteries (496 *a a*) ; but the principal part passes into the arch of the aorta (496 *e*), and thence to the descending aorta. The other column, which has passed into the left auricle, there encounters the rudimentary pulmonary veins. The contraction of this auricle drives the whole of this blood into the corresponding ventricle, from whence it passes into the arch of the aorta (496 *e*), to be again distributed to all the organs.

1094. This third phase of the circulation of the chick continues to the close of the period of incubation. At this epoch the umbilical or left allantoid artery (fig. 495 *o*) has lost much of its calibre, the arteries which are distributed at the pelvian members, having diverted the current of the blood from it. It follows, therefore, that the umbilical vein (fig. 495 *s*), no longer transmitting so much blood, is, in a great degree, atrophied, so much so, that, when the chick breaks the shell, the pedicle of the allantois (fig. 495 *s*) is broken near the point of its insertion upon the cloaca (fig. 495 *d*). The chick, therefore, issues from the shell, leaving behind it its vascular envelope,

entirely withered. Before this separation, however, and about the nineteenth day of the incubation, a remarkable circumstance occurs. The vitellus, which until then remained in front of the abdomen, passes into that cavity through the umbilical opening. When the chick issues from the shell, therefore, all that portion of the vitellus, which has not been yet used in the formation of its organs, is found in the abdomen, together with a small portion of albumen, the greater part of this last having been used in the formation of the chick at the moment that the vitellus is drawn into the abdomen.

The condition of the chick on the nineteenth day of incubation, at the moment before this residuum of the vitellus passes into the abdomen, is shown in fig. 497.

1095. The vitelline vessels, therefore, constitute part of the post-natal circulatory apparatus performing the part of chylifers by which the residuum of the vitellus is transformed into the organs, and this continues until thirteen days after the close of the period of incubation, when the residuum of the vitellus is exhausted, and the vitelline vessels suffer complete atrophy on the fourteenth day, nothing remaining of them but a little stump which is soon resorbed. From this moment the circulation of the bird suffers no further modification.

On the twenty-first day of the incubation the chick, disengaged from all the investing membranes then dried up, and already habituated to pulmonary respiration, and supplied with a provision of nourishment within its abdomen sufficient for a certain time, is ready to issue from the shell. Nothing remains but to break the walls of its prison, which, however, it could not do if nature had not armed it with an instrument for that purpose in the horny and pointed extremity of its beak. It uses this accordingly to break the shell, and after issuing from its confinement disencumbers itself of a weapon now become useless.

1096. The embryonic development of the egg dismissed from the ovary and fertilised is produced by the influence of the following external agencies: 1°. Suitable temperature. 2°. A certain hygrometric state of the surrounding air, and 3°. Exposure to a respirable atmosphere.

1097. During the period of incubation the egg must be maintained at a temperature of about 104°. If it be exposed to a more elevated temperature the development will be unduly accelerated, if to a lower temperature unduly retarded. If

the temperature be below 100° or above 108°, all development will be arrested.

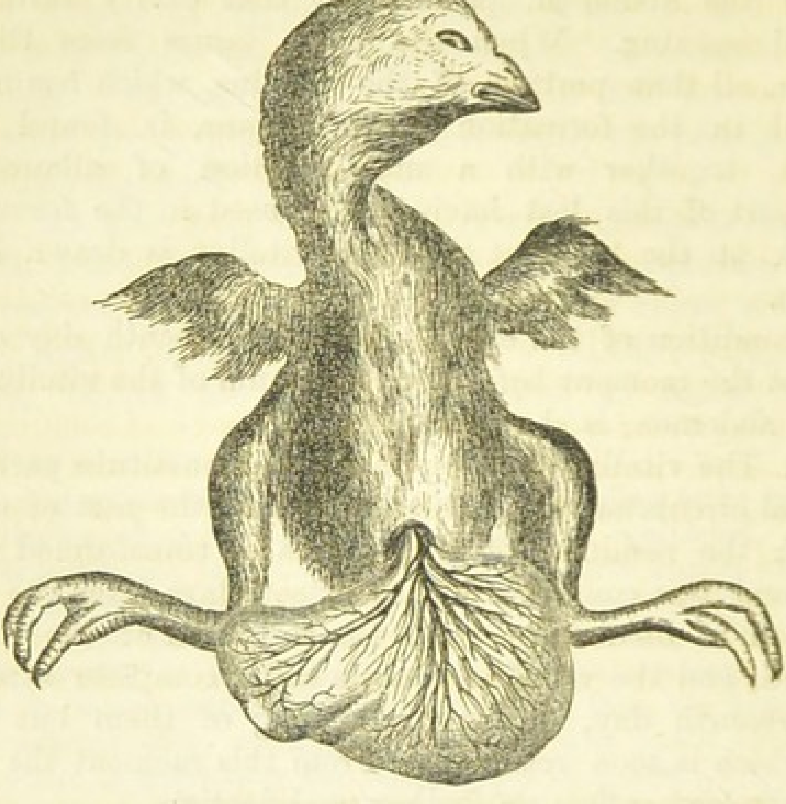


Fig. 497.

STATE OF THE EMBRYO CHICK ON THE 19TH DAY OF INCUBATION.

1098. A certain evaporation through the shell is essential to the development of the embryo. Like the temperature this evaporation, however, must be maintained within certain limits. If it be unduly accelerated or unduly obstructed, the development of the embryo is arrested. Thus, if an egg be kept in an atmosphere maintained absolutely dry by sulphuric acid, chloride of calcium, or other expedients, no development will ensue, an undue evaporation taking place through the shell, and the embryo withering. If, on the other hand the atmosphere round the egg be kept by artificial means in a state of hygrometric saturation, no evaporation through the shell can take place, and the embryo will accordingly cease to be developed.

Thus, any extraordinary deviation from the normal hygrometric state of the surrounding atmosphere, either injures the embryo or completely arrests its development.

1099. It has been ascertained by various physiologists, and recently by the researches of Messrs. Baudrimont and Martin Saint Ange, that the egg absorbs oxygen from the air, and exhales carbonic acid and a certain quantity of azote through the shell, and that this interchange of gases is essential to the development of the embryo.

Thus, if the egg be coated with an impermeable varnish or be placed in an irrespirable atmosphere, such as carbonic acid, hydrogen, or azote, all development will cease.

1100. If it be placed in an atmosphere of pure oxygen, that gas will be absorbed, and carbonic acid and azote exhaled, but the development will soon cease, and the embryo will be found to have undergone profound alterations. Its examination will show that the blood-vessels are unduly gorged and coloured; that the allantois has acquired an unnatural toughness and thickness; the amnion will be filled with cherry-red liquid containing globules of extravasated blood, much more dense than the fluid in which they float. This liquid will exhale a strong fœtid and ammoniacal odour; the albumen will be viscous and almost membranous, and in certain parts will be solidified as in a boiled egg.

1101. **Reptiles,** like birds, are generally oviparous, and produce the egg surrounded by a shell. The shell, however, is less strong than that of the bird's egg. Some reptiles, such as frogs and toads, lay their egg without a shell.

In the case of some reptiles, the incubation is partly internal, so that the egg is laid, as it were, half-hatched. With some serpents, the viper for example, the internal incubation is complete, and the animal is in fact viviparous. Few oviparous reptiles hatch their eggs. Land reptiles deposit them in sand, and amphibious in water. They are hatched in these cases by the temperature of the medium around them. Some serpents, however, coil themselves over their eggs, to which they impart a temperature a few degrees higher than the surrounding medium, which is sufficient for the development of the embryo. Certain foreign species of toads carry their ova attached to different parts of their body during the time of incubation.

1102. **The Development of Scaly Reptiles,** such as chelonians, ophidians, and saurians, takes place in the same manner as in the case of birds, the segmentation of the yolk being limited to the cicatricula. In amphibia, however, the segmenta-

tion of the yolk is complete, and the total mass of the yolk contributes to the formation of the blastema, as in the case of mammifers.

1103. **Frog's Egg.**—The successive stages of segmentation of the frog's egg are illustrated in figs. 498 to 506.

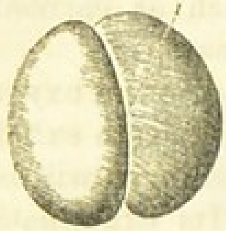


Fig. 498.

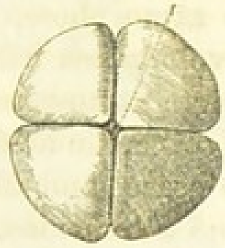


Fig. 499.

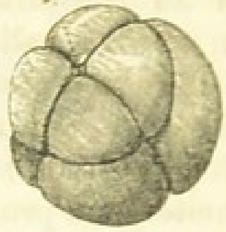


Fig. 500.

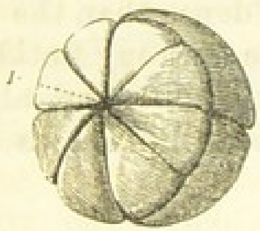


Fig. 501.

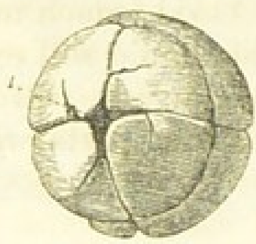


Fig. 502.

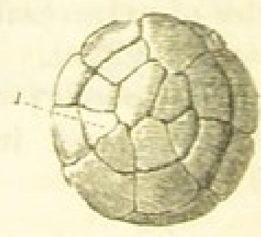


Fig. 503.

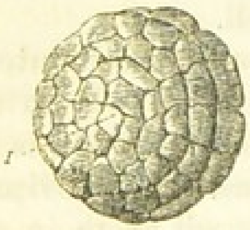


Fig. 504.

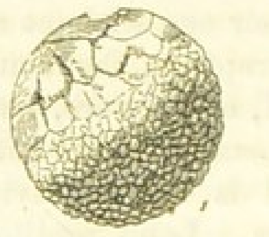


Fig. 505.

Fig. 506.

The egg of this animal presents a difference of colour in its two hemispheres, one being black, owing to the presence of a thin layer of black matter, and the other having a lighter colour. In the middle of the dark hemisphere is a point where the black stratum is interrupted, and from it a canal leads to a cavity more deeply seated in the mass of the yolk. A diameter of the egg passing through this point is called by Von Baer its *axis*, and the point itself its *pole*. The segmentation takes place according to circles drawn upon the surface of the egg similar to the meridians and parallels of latitude upon

a terrestrial globe. The first plane of segmentation takes place in the direction of a meridian, as shown in fig. 498, and the next in the direction of a meridian at right angles to it, as shown in fig. 499. These two planes of section, accordingly, divide the egg into four equal meridional zones, just as the earth would be divided by two meridians passing at right angles to each other. The next plane of segmentation is in the direction of the *equator* of the egg, as shown in fig. 500, and by this the egg is divided into eight quadrilateral parts. New meridional furrows are successively produced, as well as furrows in the direction of parallels to the equator, as shown in figs. 501, 502. At length the planes of segmentation become so multiplied, as shown in figs. 503, 504, that the egg assumes the appearance of a blackberry or raspberry ; and a still greater multiplication of them renders the surface so closely grooved, that it appears as smooth as before the segmentation commenced (figs. 505, 506). This cycle of changes is produced with extraordinary rapidity, being usually completed in twenty-four hours, after which the development of the embryo commences.

1104. Of all reptiles amphibia are the most fruitful. Tortoises lay from four to five eggs, serpents from ten to twenty, and frogs and toads several hundred. The younglings of the amphibia, on issuing from the egg, are seldom in the state to which they are destined to arrive when maturely formed, and after a certain interval undergo a metamorphosis. Thus, frogs and toads first issue from the egg in the form of tadpoles, destitute of members, having only a tail, and breathing by branchiæ placed at the sides of the neck under the skin. The development of the hind-feet is quite visible ; that of the fore-feet takes place at the same time, but beneath the skin, which they soon penetrate. The tail of the tadpole atrophises, as well as the branchiæ, and the animal soon respires by lungs, which are at the same time developed.

1105. The phenomena attending the development of the embryo of the frog and salamander have recently been submitted to a course of observation by Messrs. Baudrimont and Martin Saint Ange, not less elaborate than that which the development of the chick has received from these physiologists.

1106. **Fishes**, with some few exceptions, are oviparous. The eggs, when laid, are, however, incapable of embryonic development, until rendered fertile in the water in which they are bathed. They are usually deposited in sheltered places along the

shores and on shoals. Great numbers of them are destroyed before development commences. Nature has doubtless intended to repair this loss by the vast multitude of eggs produced, the number amounting generally to several thousands, and, in certain species, such as the sturgeon, to several millions at a single laying. Some species, such as the shark, the hammer-head, and the saw-fish, lay eggs surrounded by shells. With others, such as the ray, the eggs are hatched in the oviducts, and the animal is, in fact, viviparous. In cartilaginous fishes, which lay eggs with shells, the segmentation, as in birds' eggs, affects only a part of the yolk, which corresponds to the cicatricula.

1107. **Invertebrata** are reproduced by very various processes. Not only those which hold the highest place in the scale of organism—such as insects, arachnida, crustacea, and mollusca, but even certain zoophytes, are produced, like the higher class, by eggs. Other invertebrates are reproduced by processes, which give them the name of *fissiparous* and *gemmiparous.*

In the case of insects, the youngling which issues from the egg differs altogether in its form, organisation, and functions from the parent, and only arrives at its mature state after passing through several metamorphoses, which have been already noticed. (245, et seq.)

The eggs of invertebrate animals are subject to the same process of segmentation as has been explained in the case of the vertebrates, and are referable in relation to this phenomenon to three principal types; the *first,* in which, as in mammifers, the whole substance of the yolk is affected by the process; the *second,* in which, as in birds, the segmentation is confined to a part only of the yolk, corresponding to the cicatricula; and the *third,* in which the yolk takes no part in the process, which affects certain transparent nucleated cells, in the interior of the yolk, which are multiplied by segmentation in the same manner as the yolk itself, or part of it, is in the first two types. The substance of the yolk in this third type is gradually absorbed in the process of segmentation.

Fig. 507.—An ovum, the yolk of which is divided into two equal portions; the upper portion contains a cell with a large nucleus; the lower, a similar cell with two small nuclei. Fig. 508.—An ovum, of which the yolk is divided into four masses, three of which possess a single nucleated cell, the fourth, two such cells. Fig. 509.—An ovum, the globular masses of whose yolk amount to sixteen, in each of which a nucleated cell is clearly discernible.

An example of the first of these is presented in the ova of three

species of *ascarides*, called *nigro-venosa*, *acuminata*, and *succisa.* According to Kölliker, it would appear that as soon as the mature ovum of these entozoa passes from the oviduct, the

A B C

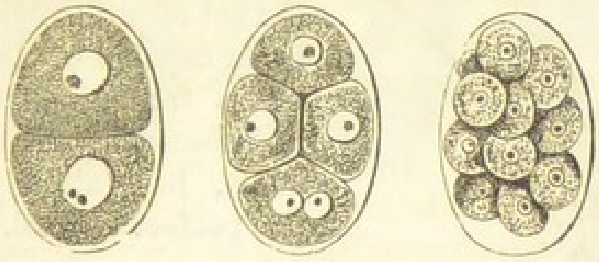


Fig. 507. Fig. 508. Fig. 509.
SEGMENTATION OF OVUM OF THE ASCARIS NIGRO-VENOSA (Kölliker).

D E

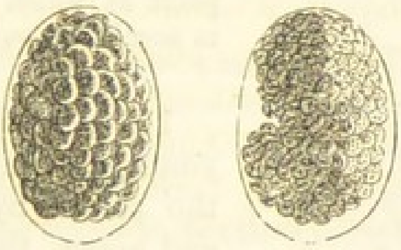


Fig. 510. Fig. 511.
SEGMENTATION OF THE OVUM OF THE ASCARIS ACUMINATA (Bagge).

germinal vesicle disappears, and a diminution of the consistence of the yolk takes place. Soon after this a new nucleated cell appears in the centre of the yolk, which then acquires a closer texture, a smaller circumference, and a more definite outline. After a time, two cells, instead of one, are seen in the interior of the yolk, cleaving into two parts, as shown in fig. 507. The segmentation continues nearly as in the superior classes, as shown in figs. 507 to 511.

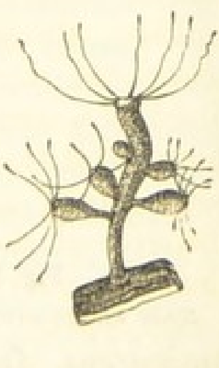


Fig. 512.
A POLYPE MULTIPLYING IN THE PROCESS OF GROWTH (Trembley).

1108. Sometimes, as in the case of certain polypes and annelids, the young is an offshoot of the parent, endowed with separate and independent vitality and a capacity for growth, so that, upon being detached from the parental body, it becomes a new individual of the same species.

Each of the individual polypes composing the Hydra (fig. 512) is actuated by an independent will, may be

separated from the rest, and is, at least in form, a perfect animal.

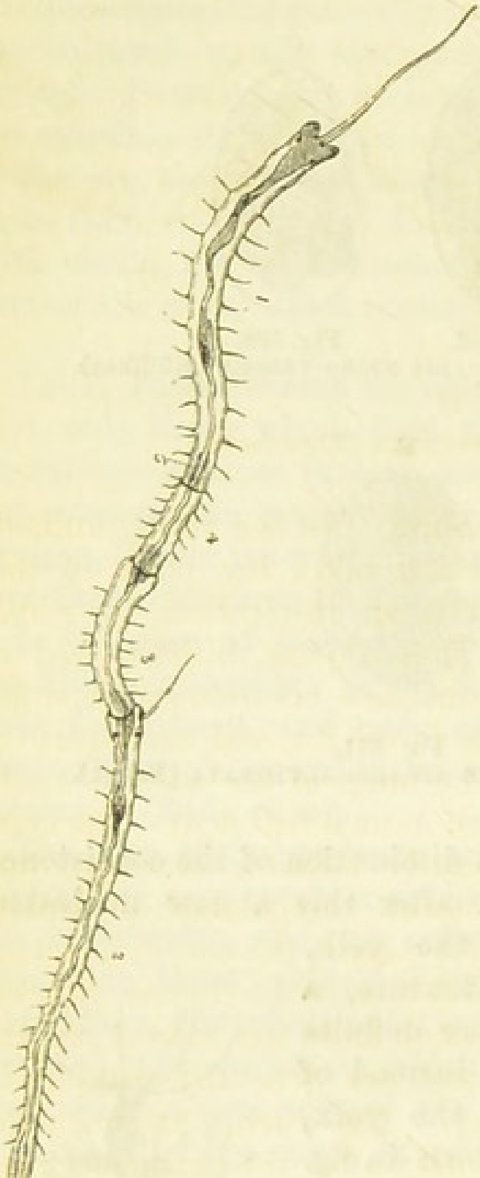


Fig. 513.

NAIS PROBOSCIDEA (Müller).

1109. When the worm, called *nais proboscidea* (fig. 513), is in the act of multiplying by growth, parts capable of detaching themselves from the parent animal, and becoming separate individuals, have already the forms of the perfect animal.

In the fig. 513, 1 is the parent, and 2, 3, and 4, young worms in successive stages of development. The point at which the young ones grow in succession out of the parent is 5.

1110. In other cases, the young animal is detached from the parent by a sort of fissure, and hence the class is denominated *fissiparous*. This mode of reproduction is frequent among infusoria. The monad divides itself into several independent monads by transverse and longitudinal fissures. The vorticella separates longitudinally into two independent vorticellæ. The successive phases of this process are illustrated in figs. 514—517.

1111. Another mode of reproduction is by buds, and the class thus multiplied is called *gemmiparous*, from the Latin word *gemma*, a bud. This process is seen in the polypifera, and in certain acephala, such as the cytais.

1112. **The Transition from Embryonic to Natural Life** is marked by several changes, the object of which is to place the new being in harmony with the medium in which it is destined to live. The most important of these is respiration. The

embryo, floating in a liquid, derived the arterialisation of its blood from the maternal organism through the intervention of

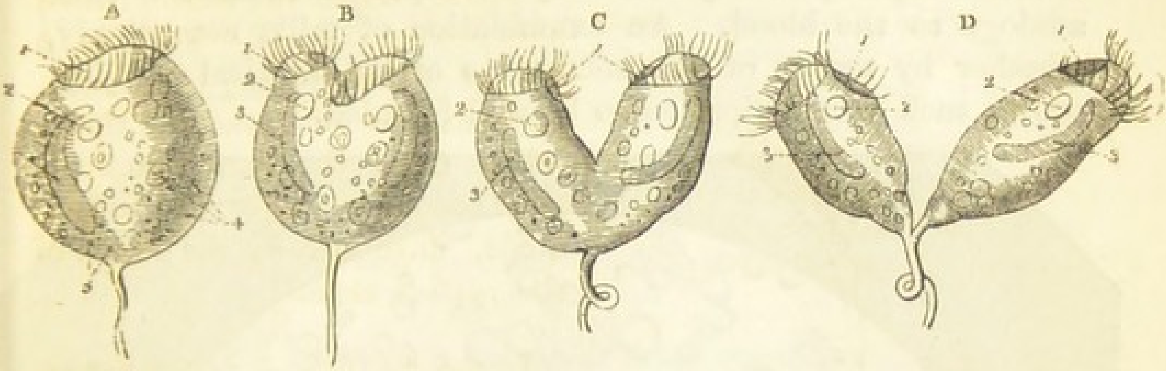


Fig. 514. Fig. 515. Fig. 516. Fig. 517.
REPRODUCTION OF THE VORTICELLA (Ehrenberg).

the umbilical vessels and the placenta. In the young animal, on coming into the world, respiration takes the place of this placental circulation. Its first act is an inspiration, by which the lungs are inflated with air. These organs, hitherto red in colour and heavy and dense in texture, now becoming pink, suffer more augmentation in volume than in weight, and consequently become, bulk for bulk, lighter. The lungs of the embryo would sink in water ; those of a new-born animal will float. The commencement of respiration necessarily infers a corresponding modification of circulation. The placenta being detached, usually by scission, the circulation through it ceases ; the umbilical artery (*i i*, fig. 477), the umbilical vein (*u*), and the ductus venosus (*d*), shrink and begin to be obliterated from the second to the fourth day of the infant's age, and are generally completely closed at the fourth or fifth day. The ductus arteriosus (*o*) begins to contract almost immediately after the commencement of respiration, and is generally closed in about a week. The foramen ovale, which during embryonic life maintains a communication between the two auricles of the heart, is soon after closed, and remains closed during life. The consequence of these changes is, that all the blood which arrives at the cavities of the left side of the heart is propelled through the lungs, and there arterialised by the effects of respiration before it returns to the left auricle. The blood which ceases to move in the arterial duct is there coagulated, the sides of the tube contract, and it is converted into fibrous cord.

1113. **Maternal Milk.**—The functions of nutrition undergo

a corresponding change. The maternal milk is now the aliment of the youngling. This fluid being its exclusive nutriment until a certain epoch, it may naturally be expected to have a close analogy to the blood. An examination of milk, accordingly, whether by means of the microscope or by chemical analysis, proves such an anticipation to be well founded.

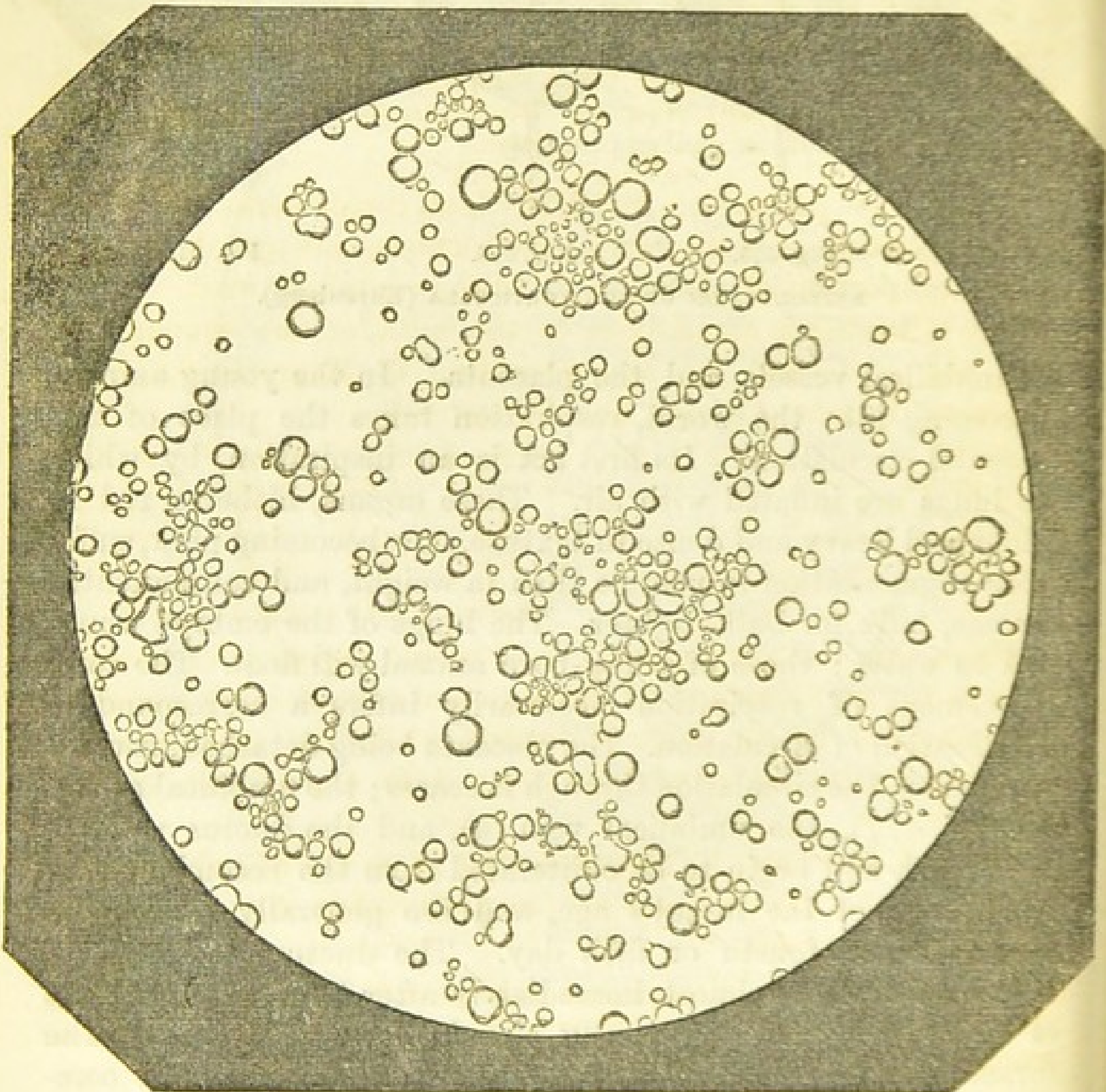


Fig. 518.

THIN DISC OF COW'S MILK, THE 120TH OF AN INCH IN DIAMETER, MAGNIFIED 400 TIMES IN ITS LINEAR DIMENSIONS. FROM A DAGUERREOTYPE BY MM. DONNÉ AND FOUCAULT.

If a small drop of milk be submitted to the microscope as a drop of blood was described to be in (442), nearly the same appearances will be manifested. A multitude of minute pearly spherules with the most perfect outline, reflecting light brilliantly from their centre, and varying in magnitude from the 12500th to the 3000th part of an inch in diameter, and even larger, are seen floating in the fluid.

The general magnitude and number of these globules vary much, not

only in the case of one species of animal compared with another, but with different individuals of the same species, and even with the same individual under different circumstances.

It appears from the researches of physiologists on this subject that the pearl-like globules, which thus float in such multitudes in milk, are the constituents out of which butter is formed. The serous fluid in which they float is composed of the constituent out of which cheese is formed, combined with another substance called sugar-of-milk, and water, the last constituting from 80 to 90 per cent. of the whole, so that, in fine, milk in general may be regarded as water holding in solution the substances called sugar-of-milk and caseine, the name given to the cheesy principle, with the globules of butter already described floating in it, besides certain salts, soluble and insoluble, in smaller proportions.

1114. The proportion in which these constituents enter into the composition of milk varies, the richness always depending on the proportion of globules of butter contained in it.

The following is an analysis of the milk of the woman, the cow, the goat, and the ass, according to Meggenhofen, Van Stiptrian, Liuscius, Bonpt, and Péligot :—

	Woman.	Cow.	Goat.	Ass.
Butter	8·97	2·68	4·56	1·29
Sugar of Milk	1·20	5·68	9·12	6·29
Cheesy matter . . .	1·93	8·95	4·38	1·95
Water	87·90	82·69	81·94	90·47
	100·00	100·00	100·00	100·00

From this and similar analyses it would appear that woman's milk is by far the richest of the mammalia, containing generally little short of 10 per cent. of butter, while the milk of other species contains no more than from 1 to 4 per cent. of that principle.

It must, however, be observed that these are average proportions, and that the richness of the milk differs considerably in different individuals.

This will explain the discrepancies observed in different analyses. Thus MM. Lehmann, Regnault, and others assign to the constituents proportions sensibly different from the above.

ANALYSIS OF WOMAN'S MILK.

	Lehmann.	Regnault.	Verons and Becquerel.
Butter	2·0	2·6	2·7
Sugar of milk and soluble salts .	4·7	4·9	4·5
Cheesy matter and insoluble salts	3·5	3·9	3·9
Water	89·8	88·6	88·9
	100·0	100·0	100·0

It is found that in all cases the milk is sufficiently rich in the cheesy principle, the constituent in which it fails being the butter, which is the most important in respect to nutriment.

The butter globules of woman's milk, though much greater in quantity, as appears above, than those in the milk of inferior animals, appear from the observations of Dr. Donné to be smaller in magnitude. We have given, in fig. 519, the appearance of a disc of woman's milk, magnified similarly to fig. 518. The difference between the magnitude of the globules is apparent.

The analogy of milk to blood, manifested in a manner so striking by the microscope, was still farther investigated in a series of highly interesting experiments made by Dr. Donné.*

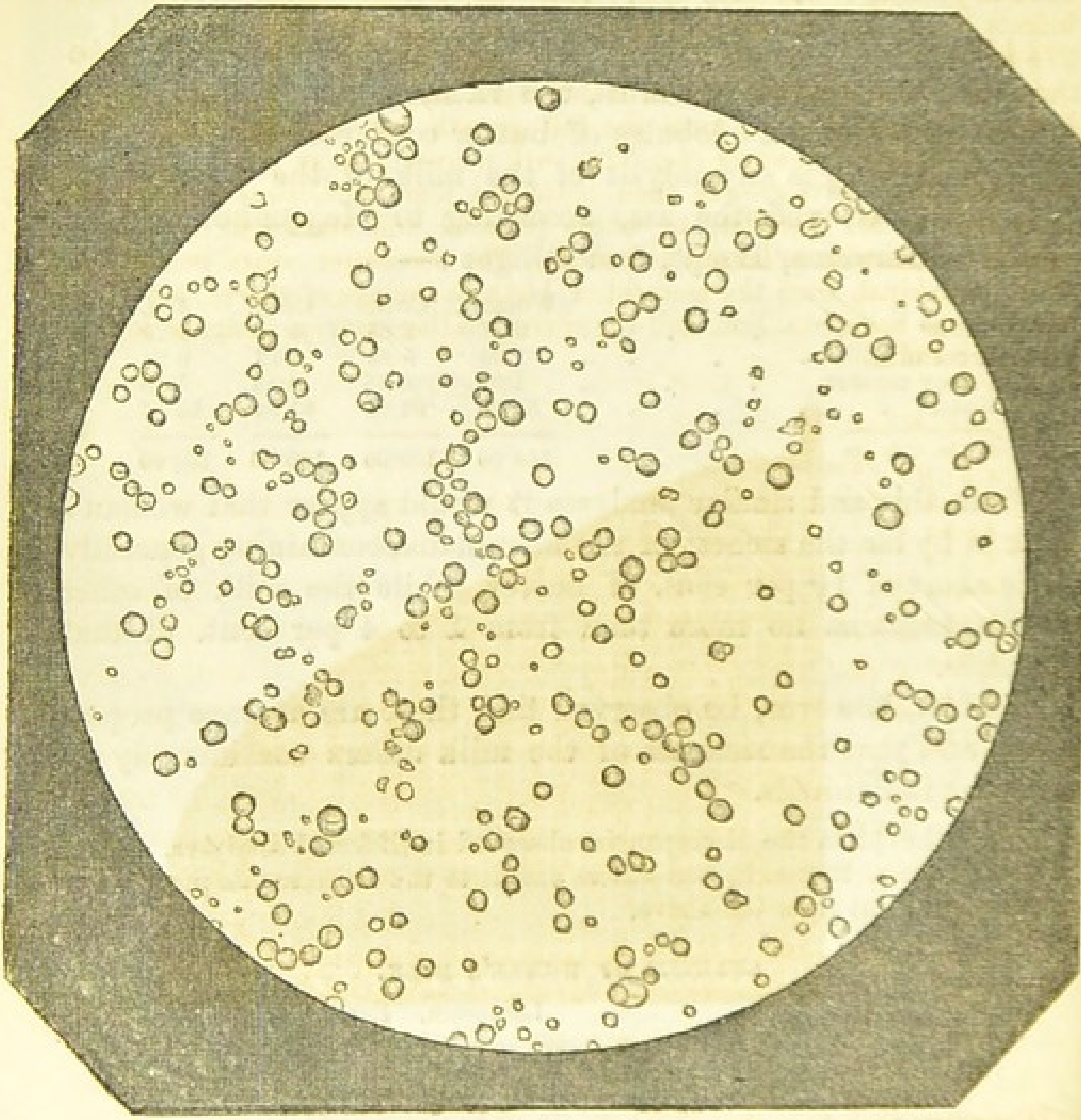


Fig. 519.

THIN DISC OF WOMAN'S MILK, THE 120TH OF AN INCH IN DIAMETER, MAGNIFIED 400 TIMES IN ITS LINEAR DIMENSIONS.

* For other details respecting the milk of animals, and the method of detecting the adulteration of milk offered for sale, the quality of the milk of wet-nurses, &c., see Lardner's Museum, vol. vi. p. 108, et seq

1115. **The First Period of Life** in all animals presents the vital functions in a state of extraordinary activity. The increase of magnitude which the body receives is so much the more rapid as the animal is younger, and each year that passes adds proportionally less to the stature than that which preceded it. A child of three years old has already attained about half the total height of the adult.

Statistical returns sufficiently exact and regular to indicate the average progressive growth of the human body, though rare, are not unattainable. In Belgium, for example, where the average stature is somewhat greater than in France, it has been found that the average height of new-born infants is 19½ inches, and at the end of the first year it is increased to 27½ inches.

In the second year the growth is less rapid, and in every succeeding year becomes less and less so, until the full growth has been attained. The annexed diagram, however (fig. 522), will convey a more exact notion of the mean progressive growth than could any mere numerical statements. It is due to M. Quetelet, to whose physical and statistical researches science is otherwise so largely indebted. The successive years in the age of an individual, from the moment of birth to the age of thirty, are indicated in the horizontal line, and the corresponding average heights in the vertical column.

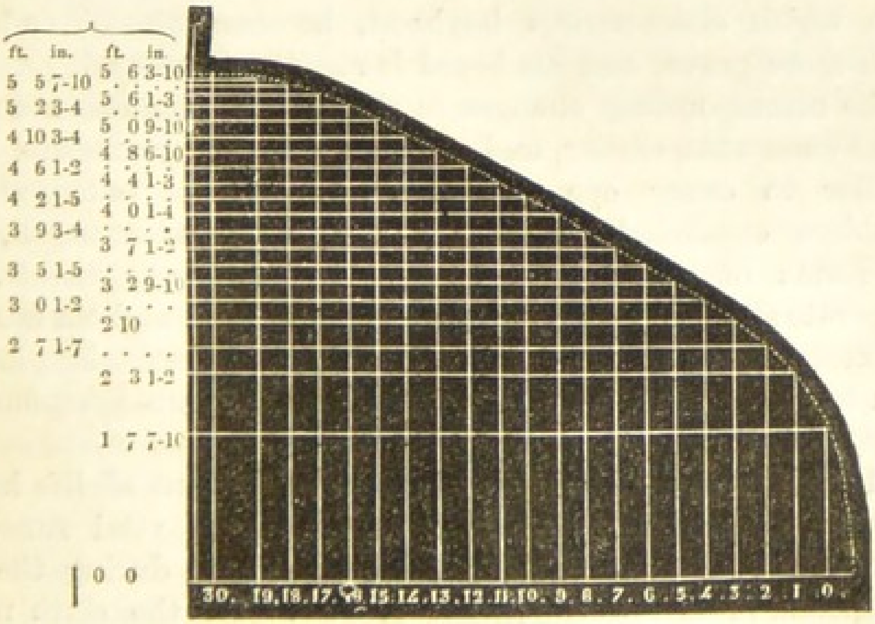


Fig. 520.

It appears, therefore, that at the moment of birth the infant has a stature equal to about two-sevenths, and at three years old, about half of its ultimate height.

At the moment of birth, the average height of boys exceeds that of girls by about the twentieth of an inch, and this difference increases with their growth. Nevertheless, the results obtained by M. Quetelet must be received merely as first approximations; the observations and inductions

necessary to establish general and certain laws being much more numerous than any which statistical records have yet supplied. It may, however, be assumed that in extreme climates, whether hot or cold, the body arrives at its full height sooner than in temperate climates; in towns sooner than in the country, and in plains sooner than in mountainous districts.

1116. The development of the body in bulk is slower than its growth in height. A new-born infant has upon an average about a twentieth of the weight which it will acquire upon attaining its greatest development, which takes place in general for men at forty and for women at fifty.

During the first year after birth, the increment of weight is about one-tenth of all that it will receive during its subsequent existence; and the increase of weight received from the fifteenth to the twentieth year is even greater than that which is acquired in the first five years.

1117. On arriving nearly at the limit of his stature, the male passing from youth to manhood undergoes several organic changes. His bones having acquired a larger proportion of the earthy constituent, have increased strength, his muscles are more developed and powerful. His voice, losing the feminine pitch which characterises boyhood, becomes almost suddenly much more grave, and his beard is rapidly developed.

The corresponding changes in the female organism are manifested somewhat earlier, and show themselves by external forms familiar to every eye. The chest becomes enlarged, the shoulders expanded, the pelvis acquires greater width, and the forms of womanhood become conspicuously visible. In temperate climates these changes are manifested at from fourteen to sixteen years of age. In warm climates they take place at from ten to eleven, and in colder countries are postponed to seventeen or eighteen.

1118. The circulation at the commencement of life has an activity corresponding to that of the other vital functions. The number of arterial pulsations per minute during the first and second month of the infant is 140. In the sixth month it is reduced to 128, in the twelfth to 120; at the close of the second year to 110, and in the adult it descends to from 75 to 80. The same series of changes are manifested in respiration. While the number of respirations of the adult vary from 15 to 18 per minute, those of new-born children range from 30 to 40.

1119. The infantile respiration develops more heat than that of the adult; and this is rendered obviously necessary, since,

independently of other considerations, the surface of the infantile body is greater in proportion to its volume than that of the adult, and consequently subject to a greater degree of cooling by radiation.

1120. The maternal milk is the proper and exclusive nutriment of the infant for the first six or eight months, about which time a semi-liquid pap, made of wheaten flour or from the crumb of stale bread pulverised, is united with it. Soon after this the food may be varied by a combination with semoline, fecula, the cream of rice, &c. Towards the end of the first year, the food may include broths made from chicken, veal, or beef, at first diluted, and later pure. In fine, at the age of from fifteen to eighteen months, the teeth having issued from the gums, mastication commences, and the infant being weaned, the transition to solid food is made, but requires to be conducted with great precaution.

The development of the teeth at the different stages of life, from infancy to adolescence, has been already explained.

1121. During these changes in the organs of taste and mastication, other modifications take place in the alimentary canal. The stomach takes a more horizontal position, and, as well as the large intestine, acquires increased capacity. The liver and the kidneys increase less rapidly than the other parts of the body, and the urinary bladder descends into the pelvis.

In coming into the world, the infant can open the eyes, but physiologists consider that it has no sense of vision, and that it is only at the end of some weeks that it begins to be sensible of visible objects. After this, it directs its looks to objects which are most brilliantly illuminated, or which are characterised by the most vivid colours. It then, by slow degrees, begins to distinguish objects around it, but it has been ascertained that a considerable time elapses before it has any idea of distances or magnitudes.

Indeed, this is quite consistent with effects which have been found to result from surgical operations in which sight has been restored to persons blind from infancy. In such cases, it has been stated that the subject of the operation, when first enabled to see, imagined that all the objects which he beheld were in immediate contact with his eyes, and had not the least idea of their relative distances, nor any other notions of their magnitudes or forms than such as were afforded by their profiles. Every object, in short, appeared as a coloured silhouette in close contiguity with the organs of vision.

1122. The other organs equally undergo a progressive improvement by exercise. During five or six months the infant makes no other vocal sound than inarticulate cries. It begins gradually to be sensible of pleasurable emotions from the contemplation of external objects, which are expressed by its smiles. The cries gradually assume the tone and character of the voice, and are accompanied by incipient efforts at articulation, and towards the close of the first year the more simple monosyllabic words are pronounced.

1123. The bones, which at the time of birth consist to a great extent of cartilage or gristle, and have no strength sufficient to support the body, receive, in the process of nutrition, a gradual accession of the earthy constituent called the phosphate of lime, which gives them hardness. Contemporaneously with this increase of strength in the bones, there is a proportionate growth and increase of strength in the muscles which move them, and about the close of the first year this strength bears such a relation to the weight of the body, that the child is enabled to support itself on its legs, and by gradual practice acquires the ability to walk.*

1124. Towards the age of five-and-twenty manhood is attained. Growth has usually ceased for some years. The parts of the skeleton which had been cartilaginous are ossified, and the perfection of solidity and strength in that structure is acquired. The functions of nutrition and assimilation have arrived at a state of equilibrium. The intellectual faculties begin to lose the passionate vivacity of adolescence : the brilliant illusions of youth giving place to the sober maturity of masculine judgment.

The ardour and often the delicacy and refinement of love is abated from year to year, and a tendency to less elevated sentiments is manifested, which, however, is controlled and more or less suppressed by moral restraint, and still more by the indirect influence of the love of children, which strengthens the conjugal affection.

1125. Towards sixty, the energies in most cases are gradually decreased. Active life has reached its term. Decline is manifested, and the signs of old age begin to appear.

At length that epoch comes. The tissues soften. The visage becomes lined and wrinkled. The hairs are sparse and white. The teeth loosen, and, one by one, fall. Digestion is enfeebled,

* On this subject, see Lardner's Museum, Tract on Man, vol. viii.

circulation slackened. Ossification invades the vascular system so as to impede assimilation.

The organs of sense become obtuse, the sight confused, the hearing dull. The movements are slow and difficult. The muscles are less obedient to the nerves ; the nerves less obedient to the will. The bones become harder and more brittle. The voice, losing its clearness and purity, is cracked. Year after year decadence progresses, and at length the cessation of the functions of respiration and circulation closes an existence which has ceased to share in the maintenance of the organised world.*

* Death, however, by the mere effect of age, is extremely rare, being in most cases produced by accidental causes, to which imprudence exposes us. Innumerable examples prove to how great an extent life may be prolonged beyond its average limits. Without citing the extraordinary examples of longevity found in the records of the first ages of the world, supplied by the Sacred Scriptures, examples sufficiently numerous may be produced nearly from our own times.

One of the most remarkable examples of longevity which modern times have presented, is that of a poor fisherman, an inhabitant of Yorkshire, by name Henry Jenkins, who died in 1670, at the ageof 157. Peculiar circumstances have incidentally supplied evidence of the great ages of this individual and two of his sons. He was summoned on a certain occasion before a court of justice, to give evidence of a fact which had occurred 140 years previously; and he appeared before the tribunal attended by his two sons, the younger of whom had attained the age of 100, and the elder that of 102. Various other examples are cited of nearly equal longevity, but for the most part they refer to times or places at which the registers of births and deaths were not kept with such regularity as to entitle the statement to confidence. It is, however, extremely rare to find an individual who has exceeded the age of 100. According to the bills of mortality of the City of London, it appears that, of 47000 deaths which took place in the ten years ending in 1762, there were only 15 centenarians. In France, during the three years ending with 1840, there were 2,434993 deaths, of which 439 were reputed centenarians, which would give a proportion of about one in 5500. — *Lardner's Museum*, vol. viii., p. 71, *et seq.*

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