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CIRRHOPODA;

BY

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CIRRHOPODA.

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CIRRHOPODA; *Cirripedia; Cirripeds;* (κιρρὸς and ποῦς, *cirrus* and *pes*, from the curl-like form which the coiled feet or arms present. Fr. *Cirripèdes.* Ger. *Rankenfuesser.*) A class of invertebrate animals, composed chiefly of the barnacles and acorn-shells. They are related in some points of structure with the annulated or diploneurose animals, particularly with Crustacea; in other points they resemble Acephala (Conchifera). All are marine and fixed. The soft parts are, for the most part, encased in a multivalve shell. The body is somewhat conical in form, tumid, and bent inwards at the oral extremity, tapering towards the opposite extremity, where it terminates in a long pointed tube. Placed along the abdominal surface, there are two rows of fleshy lobes, (six on either side,) each having two long horny processes, jointed and ciliated. In some species, these constitute the chief bulk of the whole animal. The head is indistinctly defined, and has neither eyes nor tentacles; mouth with lips, and three pairs of horny jaws; anus at the base of the tubular process. Respiration is effected by branchiæ, which, in some species, are filamentary, in others foliated. Mantle membranous, sacculated, provided with a slit-like opening for the passage of the arms, &c. Between each two pairs of arms, the abdominal surface is marked by six slight depressions, which may be regarded as an approach towards complete articulation.

The animals thus characterized have had different places assigned to them in the various systematic arrangements of modern zoologists. Cuvier formed of them the sixth and last class of his Mollusca. Lamarck was at one period inclined to place them amongst the Crustacea, but latterly he constituted for them a distinct class, and placed it between Annelida and Conchifera; still, however, regarding them as more closely allied to Crustacea than to any other class; "for," as he remarked, "they have the nervous system of Crustacea, they have jaws analogous to those of the animals of that class, and their tentacle-like arms resemble the antennæ of the lobsters."* Burmeister also places them amongst the Crustacea. De Blainville arranges them, under the name of Nematopoda, as a class of his subtype of the Mollusca — Mollusc-articulata; the other class of the subtype being formed of the Chitons (Polyplakiphora). He regards them as Crustaceous Mollusca, but admits that they seem to form a transition group uniting the Crustacea with the Annelida. M. St. Ange,* however, would rather class them with the Annelida, on account of the closer resemblance which the arrangement of their nervous system bears to that of these animals. Professor Wagner does not doubt that they are really articulated animals, but he would rather place them in a distinct class between the Mollusca and Articulata. Setting aside their nervous system, M. Serres sees, in the other parts of their structure, points enough to induce him to arrange them with the Mollusca. The same views are entertained by Wiegmann, Goldfuss, and others. Dr. Leach regarded them as truly annulose animals. Dr. Grant (who calls them "entomoid animals enclosed in shells") places them amongst the Articulata, or diploneurose animals, between Rotifera and Annelida, making of them a distinct class, but admitting their great resemblance in many points to the entomostracous Crustacea. Mr. J. V. Thompson (whose admirable researches on the development of the Cirripeds have thrown a new interest around them) holds it as proved by his observations that the Cirripeds do not constitute a *distinct class;* but that they are naturally and closely connected, on the one hand, with the Decapod Crustacea, through the Balanids, and, on the other, with the Entomostraca, through the Lepads; further, that they have no relation with the Testacea.

All the known Cirripeds may be naturally grouped into two families, one pedunculated, the other sessile. The former includes all the barnacles, properly so called; the latter, the acorn-shells. The barnacle family have had the name of Campylosomata applied to them by Dr. Leach, who calls the other family Acamtosomata: but we shall use De Blainville's synonyms of Lepadicea and Balanidea. The following are the names of the genera generally used at present:—

I. Lepadicea.
1. Otion. 2. Cineras. 3. Anatifa. 4. Pollicipes. 5. Scalpellum.

II. Balanidea.
1. Balanus. 2. Ochthosia. 3. Conia. 4. Creusia. 5 Clisia. 6. Pyrgoma. 7. Acasta. 8. Coronula. 9. Tubicinella. 10. Chelonobia.

External coverings and organs of support.— There are three principal modifications of the tegumentary organs in this class. The first is that seen in Anatifa, in which it assumes the form of calcareous plates, united by horny ligament, and attached to a cartilaginous peduncle. The second form is that common to

* An. sans Vertèbres, v. 377.

* Mém. sur les Cirripèdes. Paris, 1835.

all the Balanids—a calcareous cone, composed of separable pieces, sessile, and provided with an opercule of shelly plates. The third form is a general cartilaginous covering, sometimes strengthened by small calcareous plates.

The shells of the Cirripeds are similar in general appearance to those of many Acephalous Mollusca. They are most fully developed in Anatifa, which has five separate plates, four placed laterally in pairs, and one median.

Fig. 1.

One pair is considerably larger than the other (*c*, *fig.* 1); it covers all the anterior part of the animal, and the greater part of the internal organs. The bases of these shells are attached to the cartilaginous peduncle; the lower halves of their anterior edges form part of the margin of the slit-like opening through which the arms are protruded (*f*, *g*, *fig.* 1). The inferior pair of shells (*d*) are of a triangular form; the smallest side completes the margin of the brachial orifice; another side is united by ligament to the upper valve; the third is connected with its fellow by the common intervalvular ligament. The median piece (*e*) covers the dorsal aspect of the animal. It has an elongated lanceolate shape, curved and grooved internally. Its upper point only is inserted into the peduncle. Its margins are imbedded in the intervalvular ligament. This piece may be compared to the unpaired valve of the shell of *Pholas*: it occupies nearly the same situation. The surface of these shells is generally denuded of epidermis, excepting just around their margins. All three are strongly and regularly marked with lines of growth, from which it is seen that the two pairs of lateral valves increase in size, chiefly, by additions to their margins, which look towards one another; so that the parts first formed are, in the adult animal, removed to the greatest possible distance from one another. In the upper valve, the umbo or centre of growth is situated in the anterior-superior angle, close to the termination of the peduncle; in the lower, it is situated in the anterior-inferior angle; and in the dorsal valve, in the point next to the peduncle. All the shells are thin, diaphanous, of nearly the same thickness throughout, yet much less fragile than shells of Acephalous Mollusca which otherwise resemble them. It has been remarked by Burmeister that the shells of Cirripeds resemble those of crustaceous animals more than those of Molluscs: to us it appears that they have a greater degree of density, and a more compact crystalline structure than are commonly met with in Crabs; and that their well-marked lines of growth give them a closer resemblance to shells of acephalous mollusca. In some genera, as Pollicipes, in addition to the five valves just described, there are other eight smaller calcareous plates arranged around the junction of the peduncle with the shells.

The shells of the Balanids present several striking peculiarities of structure, and, in their mode of growth, offer to the physiologist an interesting subject for investigation. They form truncated cones, the bases of which, without the intervention of peduncles, are fixed to rocks, floating wood, integuments of marine animals, &c. These cones are composed of several pieces, closely cemented together so as to admit of no motion between them, excepting during the process of enlargement of the shell. In the common acorn-shells (*fig.* 2), which cover our littoral rocks and the bottoms of ships, there are seven of these pieces, six forming the walls, and one discoid, forming the base. The outer surface of the parietal valves is marked by the lines of growth in such a manner as to give it the appearance of being composed of twelve pieces. These may be termed *compartments*. They are all conical. Six of them have their bases applied to the common base of the shell, and the other six are inserted between these, with their apices towards the common base. The first six we shall refer to under the name of the *first series* of compartments (*a*, *a*, *fig.* 2); the other six constitute the *second series* (*b*, *b*, *fig.* 2). The opening in the summit of the cone is closed by an opercule composed of four shelly pieces so arranged as to leave a longitudinal fissure between them, through which the arms are protruded (*c*, *fig.* 2). The two series of compartments differ much from one another in their external aspect, owing to the differences in the directions and appearances of the lines of growth. The second series have a smoother surface, and are marked with very delicate lines, both longitudinal and transverse; they are also less prominent than the first series. The lines on the first series are chiefly transverse, and correspond with the outline of the base. On the internal surface of the walls there are six deep grooves, in the bottoms of which are seen the openings into certain chambers, constituting a sort of diploë of the valves, hereafter to be described. These grooves run from the summit to the base of the shell, and are the internal edges of the sutures of the six parietal valves. Around the internal margin of the common base there is a series of holes opening into certain tubes that terminate on the outer margin of the shell. When all the valves are separated at the sutures, it is found that each of four of the six compartments

Fig. 2.

of the first series, as they appear externally, has attached to its dorsal margin one of the second series, and that the union between these two is exceedingly intimate, in fact that they form one piece, notwithstanding their apparent division externally. Two of the second series of compartments are attached to the anterior valve, while the dorsal valve has none. The anteal margins of the lateral valves and both margins of the dorsal valve are marked by transverse depressions corresponding to the numerous partitions of the chambered compartments which are fitted into them; and, externally, each has a projecting margin. To the upper part of the inner surface of each valve there is attached a laminated process, forming part of a circle of calcareous plates which gives support to some parts of the mantle.

The internal structure of these shells presents some peculiar features. They all contain numerous tubes and cavities, regularly arranged, and forming a sort of diploë. The suture-holes mentioned above open each into a separate canal, chamber, or tube. Those which occur in rows on the walls of the cone lead to small chambers within the second series of compartments, running parallel with the general base, and separated from one another by delicately-formed partitions, each of which is deeply grooved on both sides. The partitions are placed at equal distances, and their grooves are most regularly formed. The whole presents one of the most beautiful and delicate pieces of structure with which we are acquainted in the whole range of extravascular skeletons. These are from thirteen to fifteen on either side of each partition. *Fig.* 3 represents a perpendicular section of a few of these grooved partitions considerably magnified. *Fig.* 4 represents a horizontal section of one of the six valves. The holes forming the sutures are at *a*. The grooved floor of one of the chambers of the piece is between *a*, *d*, and *c*. *d*, *c* is the outer wall of the compartment of the second series. *a*, *b* is a section of that part of the valve which appears outside as a compartment of the first series. Its diploë is composed of tubes, running from the apex to the base, gradually enlarging below. Horizontal sections of those tubes shew them to be of an ovate form, tapering inwardly (*fig.* 5). They are placed nearer the outer wall than the inner. The spaces intervening between the tapering sides of the tubes are marked with lines of growth, shewing a gradual filling up of the tubes from within outwards; and also the previous existence of furrows or grooves on the surfaces of the partitions between the tubes. These grooves are very strongly marked in some species, as in *Balanus Spinosus* (*fig.* 6), where the tubes are large, and the walls comparatively thin. In all they run in straight diverging lines from the apices of the compartments to their bases. There they open close to the margin of the general base. In most species, however, their orifices are, in part, filled up by an extension of the base (*a*, *fig.* 7). In some small species, the tubes of which are wider than those of larger ones, there is hardly any opening discoverable externally, or at most a very narrow fissure just around the margin. Very near their terminations on the margin, these tubes of the diploë are joined by the very short canals which proceed from the inner circumference of the base (*b*, *fig.* 7), and it is at their junction that the grooves in the walls of the partitions are most obvious. These two sets of tubes communicate freely all around the margin with the diploë of the base. All the Balanids—with the exception of the Coronules—have calcareous bases. The structure of the base differs from that of the walls in being composed internally of large oval cells irregularly arranged. These cells seem to communicate freely with one another and with the tubes of the valves. The Coronules have no base: their soft parts are in immediate contact with the integuments of the living animals in which they are generally imbedded.

Fig. 3.

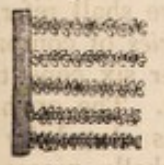


Fig. 4.

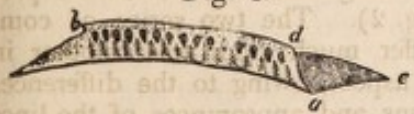


Fig. 5.

Fig. 6.

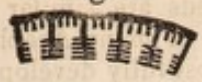


Fig. 7.

The form and arrangement of the opercule vary. There are generally four triangular valves, two larger than the others, all deeply grooved on their upper surfaces by the lines of growth. These valves cover more or less completely the soft parts beneath, to which they are attached, so as to be very moveable one upon the other, and to admit of the passage of the feet through the slit that exists between the two pairs. In some of the coronules, the greater part of the opercule is soft. *Coronula diadema* has two small shelly plates in its opercule.

Keeping in view the complex but beautiful structure just described, it is not difficult to determine how the whole shell increases in size. It is obvious that the parietal compartments of the first series are enlarged by additions to their basilar edges and internal surface, and that thus the whole cone is lengthened, and consequently widened at its base; but, in all the species, it is also widened above; and, as the summits of the first series of compartments are, evidently, not at all, or, at most, very slightly, abraded by the friction of the opercule, it is certain that the apices of these compartments—originally very closely approximated—must be moved outwards and separated from one another by the gradual increase in breadth of the intervening wedge-like compartments of the second series. This process

implies the insertion of soft parts endowed with vascular action between the valves so as to admit of lateral additions being made to the second set of compartments. There can be no question that these soft parts (foliated processes of the mantle) pass into the sutures along their whole length, and deposit the shelly matter on the edges of the partitions forming the chambered structure of the second series of compartments; each valve, with the exception of the dorsal one, is thus added to in breadth; and as the distance between the original valves is enlarged, and the whole shell lengthened, new chambers are formed below. Of course, as the cone is lengthened, its base is widened; and this is effected by the excretion of shelly matter from such parts of the mantle as can easily pass through the numerous holes placed around the inner circumference of the base. The valves of the opercule are imbedded in the margins of the mantle between the epidermis and true skin, and are increased by marginal additions in the same way as the shells of molluscs.

The mode of growth of these shells engaged the attention of Cuvier, who concluded that an addition to the sides of the valves could take place only in an early age; for it appeared to him that they are, in a more advanced stage, so firmly cemented together as not to admit of separation. In large species, however, we find that the valves are easily separated at the sutures, and that the calcareous matter along the sides of the sutures is loosely aggregated; so that, to us, there seems to be no improbability in the supposition that in the living animal the prolongations of the mantle pass between the terminations of the minute tubular processes of the second series of compartments, and the corresponding depressions in the edges of the first series already noticed. There is no indication, we think, of each of the valves being "detached from its neighbour *only* at certain times that it may receive additional calcareous matter along its sides," as Brugières and Cuvier imagined. The process of growth seems to be carried on in uniform progression until adult age. So puzzling did the problem of the mode of growth in these shells appear to Dufresne, that he concluded that, like crabs, the Balanid casts its old shell, and forms a new one, as it increases in size.* Cuvier remarked that, "while the mode of growth of the shells of the Mollusca resembles that of simple teeth, the organization and increase of the shells of balanids may be compared to that of certain compound teeth, particularly those of diodons and tetrodons."

Tubicinella, a parasite of the Whale, differs much from the other balanids in the formation of its shell. The widest part of its six-valved cone is superior; the whole surface is strongly ribbed, and marked with transverse lines of growth; and it appears that the additions to the cone are made on the upper margin; this margin is surrounded internally by a thick and fleshy production of the mantle, which is never altogether covered by the opercule. The base is open, and of little less diameter than the upper part, which led Dufresne to conclude that the animal does not form a shell until it be considerably advanced in growth. This seems to be very probable, as the base is imbedded deeply in the integument of the Whale, and descends lower the more it increases in size, so as to leave only the summit of the shell visible. The imbedded portion is generally deeply coloured by the tegumentary pigment of the Whale. In coronula, which also inhabits the backs of Whales, but has the same general structure of shell as the majority of Balanids, the valves are deeply partitioned, and provided with toothed processes, fitted to fix the animal in its site.

The only other calcareous coverings that remain to be noticed are the rudimentary valves in *Otion* and *Cineras*, animals that bear a general resemblance in form to *Anatifa*, but which are covered chiefly by a semicartilaginous tunic. There are two small valves in Otion, which are attached to the anterior aspect just above the brachial orifice. In Cineras they are five in number, two in the same situation as those of Otion, two along the terminal margin of the outer tunic, and one unpaired along the dorsal aspect. These are imbedded by their margins in the semi-cartilaginous tunic, and seem to be formed by it; calcareous matter being added to their margins in successive layers.

The ligamentous membrane, by which the valves in *Anatifa* are connected one with the other and with the peduncle, is strong but pliant. It is an extension of the outer covering of the peduncle. At the brachial orifice, it is reflected inwards to join the mantle. In addition to this, each valve has a membrane of its own, which closely invests its inner surface, and is not continuous with those of the other valves. The peduncle of this and the allied genera may be considered as a kind of developed ligament. If we regard the upper pair of valves as analogous to the valves of Acephalous Mollusca, the peduncle is found to be attached to them at points corresponding to the situation of the ligament in those shells. This organ is sometimes of great size. In the British seas it occasionally occurs two feet in length. Its epidermis is generally rough, wrinkled transversely, coriaceous, and elastic: Otion, however, has it very smooth and stiff, nearly cartilaginous, diaphanous. In some species it is so elastic as to admit of extensive lateral motion, and much elongation and contraction. These movements are effected by a layer of strong muscular tissue beneath the skin, within which there is a large organ, granular in its structure, regarded by some anatomists as the ovary. Burmeister is of opinion that the peduncle is merely an organ of support: and he suggests that the granular parenchymatous mass, which fills its interior, is destined solely for its own nutrition, which he seems to think is independent of the other parts of the animal. In most species, it is by its epidermis that the peduncle adheres. The peduncle pre-

* Ann. du Mus. i. 467.

sents still other varieties than those just mentioned. *Pollicipes villosus* has it covered partly with imbricated scales, and partly with a hairy coat; and *Pollicipes quadrivalvis* has its valves wholly encased in a large prolongation of the peduncle, which, on its upper surface, bears four valves arranged nearly in the same way as those of the opercule of the Balanids. The base of Coronula is closed by a strong fibrous membrane connected with the body of the animal only by a process of the epidermis. It is regarded by Burmeister as the analogue of the peduncle of the Lepads.

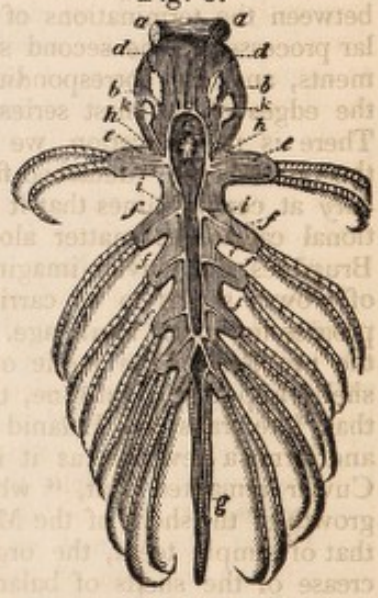
The cartilaginous tunic of *Otion Cuvieri*, at its summit, is enlarged into two large auriform appendages, hollow, having a crescentic orifice externally, and internally communicating with the visceral cavity of the animal; no organ is discoverable within them, but their cavities receive the terminations of a duct, which descends on the dorsal aspect of the body, in the groove of the dorsal valve, from the peduncle.

Of the mantle, as one of the tegumentary organs of the Cirripeds, little more need be said, than that it is generally a very thin transparent membranous sac, surrounding the visceral mass, open only at the brachial orifice, where it joins the epidermis and intervalvular ligament, and is reflected so as to form an inner lining for the visceral cavity. It has neither fringes of filaments, nor foliated processes. M. St. Ange describes another tunic of the visceral mass, which, he says, is continuous with the horny covering of the arms.

Locomotion.—Their base being permanently fixed, the principal motions of the Cirripeds are those of the arms, which seem to be subservient at once to the respiratory and to the digestive functions. But, as has just been mentioned above, the peduncle of Anatifa and other allied genera is moved both laterally and in the way of contraction and extension, and the valves, in the same animals, are so moved as to open and close the brachial orifice. The motions of the arms are, in many species, very rapid, and are performed with great regularity; proving the existence of a complete muscular apparatus both at their bases and within their numerous joints; but the parts are too minute to admit of a satisfactory examination being made of their structure. The Lepads have a strong transverse adductor muscle placed between their superior valves, just above the brachial orifice (*a*, *fig.* 9); this muscle seems to be every way analogous to the same organ in Acephala. Its action closes the brachial slit very accurately; while its relaxation admits of its being opened by the advance of the arms grouped together into the form of a wedge. This movement of the arms cannot be performed without the whole body being carried outwards; which is effected apparently by the contraction of certain delicate muscular fibres spread over the mantle, and attached around the margin of the orifice. Cuvier describes a similar set of fibres, "attached to the mantle opposite the insertion of the peduncle, by the action of which the general mass of the body is drawn deeply within the shell." This we have failed to observe in the species which have come under our notice. When the arms are fully exserted, they are separated one from the other, fan-like. This motion is probably produced by a muscular expansion, described by M. St. Ange as covering the visceral mass dorsally, the fibres of which are grouped into six bundles on either side, corresponding to the arms. The same observer describes also certain tendons which he found crossing one another at the median line; these are probably connected with another layer of muscles, expanded over the dorsal surface of the visceral mass, fitted to approximate the arms of either side towards one another. The muscles of the jaws cannot be satisfactorily examined on account of their minuteness. In the Balanids, the valvular opercule is moved by a set of muscles attached to the circle of shelly plates that surround the opening of the parietal cone. Its adductors, which close the aperture with great force, are attached to the extremities of the valves on either side. The visceral mass is, in the Balanids, fixed to the shell by three muscular bands, partly attached, around the mouth, to a process of the epidermis, and partly spread over the mantle.

Motility and Sensation.—The nervous system of the Cirripeds consists essentially of two nervous cords running along the abdominal surface, and swelling out into distinctly formed ganglions, at intervals corresponding to the feet-bearing lobes. The first pair of ganglions is situated above the œsophagus (*fig.* 8.) They are united by a very short nervous cord.—From this supra-œsophageal ganglion and the uniting cord, there arise anteriorly three or four nerves, which are distributed to the muscular tunics. The principal nervous cords, leaving the first ganglion posteriorly, descend to encircle the œsophagus. In this course, they give off branches to the salivary glands and other neighbouring parts, and particularly, (as M. St. Ange has pointed out,) a nerve of communication with a small lateral ganglion (*k*, *k*, *fig.* 8) on either side, situated near the stomach and below the salivary organs. This is connected also with the second pair of ganglions. From this second pair, several branches arise, some of which go to the stomach, and two to the first pair of arms. The other arms receive only one branch each (*i*, *i*), which is divided into

Fig. 8.



two, one for each of the jointed processes. In its course along the abdominal surface, the double ganglionic cord—the centre of the nervous system—lies immediately beneath the skin, between the bases of the arms. The fifth and the sixth pairs of ganglions have the appearance of being closely united. The tubular process, which terminates the anal extremity of the body receives two nerves, one from each of those going to the sixth pair of arms. Dr. Grant directs our attention to the fact that all the anterior parts of this system are very imperfectly developed compared with the posterior parts, and with the same parts in other articulated animals, which have their heads free, and organs of sense more complete.

The sense of touch is the only one enjoyed by the Cirripeds, so far as we can discover. The ciliated arms of some of the species are acutely sensitive: they are withdrawn immediately on being touched by any foreign body, and when the surrounding fluid is unfit for respiration. Some observers have also remarked that they shrink from a strong light brought to shine upon them suddenly. In the adult animals, there are certainly no organs which can be regarded as eyes; but, according to Mr. Thompson, what he believes to be the free-moving young have very well developed eyes, like those of some crustacea.

Some of the littoral Cirripeds, when left dry at ebb-tide, seem to be sensible of certain changes being produced in the state of the surrounding air by the approach of a living being to the place of their habitation. We have frequently remarked, on drawing near a spot densely peopled by the small acorn-shells that so abundantly cover most of our rocks on the sea-shore, a peculiar faint crackling noise, suddenly produced, gradually subsiding after the lapse of a few seconds, and not repeated until a movement was made towards another spot; and, on searching for the cause of this singular sound, we have satisfied ourselves that it is uniformly produced by the sudden closing of the opercules of the Balanids, which seem generally to remain open in ordinary circumstances. We have seen this motion again and again follow immediately the movement of the hand towards particular spots, (not, however, nearer the shells than twelve or fourteen inches,) so that we could not but conclude that the animal was made sensible, through the medium of the air, of the presence of some foreign body, and, fearing danger, closed its shell for self-protection; just as the limpet, warned of the approach of hurtful agents by the slightest touch of its shell, fixes itself more securely to its rocky footing. What the nature of the sense is which is thus used by the Cirripeds, we have no means of determining.

Digestion.—The minute swimming Crustacea appear to constitute the principal food of the Cirripeds. Sometimes, however, the shells of minute Mollusca are found in their stomachs, and Burmeister once found part of an annelid of unknown species. The food is carried towards the mouth by currents produced by the rapid motions of the arms, which, in most of the species, are constantly spread out and drawn in, alternately, with great regularity. The mouth is situated just at the bottom of the funnel-shaped cavity formed by the spread arms (*b*, *fig.* 9). In the Lepads its position is close to the transverse adductor muscle. Its jaws form a round protuberance, which presents itself very conspicuously immediately on separating the arms. It might almost be regarded as a head, so prominent is it (*fig.* 10, *b*, *b*); but we find it composed only of the lip and jaws, with their muscles. The lip over-arches the jaws; it is horny, and furnished with minute palpi. There are three pairs of jaws. The first or outer pair are thin horny plates of an oval form, fringed along their opposing sides with long stiff hairs. The other two pairs are curved and deeply serrated on their opposed surfaces. The middle pair bears a small palp on its lateral margin. In some species, a small tongue has been found. All these parts bear a close resemblance to the same organs in some of the Crustacea. The œsophagus is short; its lining membrane is somewhat horny, stiff enough permanently to distend the whole canal; before entering the stomach, its diameter is considerably enlarged. It receives the ducts of two salivary glands. The stomach (*c*, *fig.* 10) is capacious; externally, it presents an irregular mamillated surface, studded with numerous small prominences closely set, which are the outer surfaces of hepatic cells, formed in a layer of glandular tissue that closely invests the walls of the stomach. These cells communicate directly with its general cavity (*a*, *fig.* 11). There is no other organ that can be regarded as a liver.* Two cœcal appen-

Fig. 9.

Fig. 10.

* Burmeister's recent researches have led him to conclude that both the Lepads and the Balanids have large livers. He has satisfied himself that the organs, regarded by Cuvier as the ovaries, and by more recent authorities as the testicles, communicate by ducts with the upper part of the intestinal canal, and not at all with the seminal vessels. Hence he supposes that they are lobes of the liver and not organs of reproduction. Our own dissections lead us rather to agree with Messrs. Wagner and St. Ange, who believe them to be the testicles.

dages, also sacculated internally, and embossed outwardly, are attached to the stomach.

Fig. 11.

The intestine is wide, nearly without convolutions, and tapering towards the anus (*d*, *e*, *fig.* 10). In the Lepads the stomach is situated in that part of the visceral mass nearest to the peduncle; from which point the intestine runs on the dorsal aspect of the body, and terminates in the anus just at the base of the articulated tubular process. It is slightly dilated near the anus. The walls of the intestine are perfectly smooth and free from folds and duplications. The number of their tunics cannot be satisfactorily determined. M. St. Ange has described a singular piece of structure which he has found within the intestinal canal of certain Anatifæ (*c*, *c*, *fig.* 11.) It is a kind of second intestine, which floats within the cavity of the one just described. It is nearly equal in length to the outer canal. Its upper extremity is expanded, funnel-shaped, with edges cut into fringed processes like the mouths of the Fallopian tube in vertebrate animals. These processes are lodged in the cells of the walls of the stomach, and furnish the only means of attachment to the outer walls with which the organ is provided. It thence tapers towards the anal extremity, where it is pointed and closed. Its walls are very thin and delicate. It is generally filled with alimentary matter, which must pass from its cavity by a kind of rumination, so as to enter the stomach a second time.

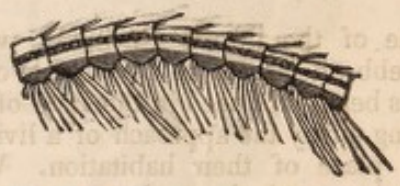
Circulation.—The sanguiferous system of the Cirripeds has not yet been fully investigated. Only the vessels of the arms, and a central canal, situated on the dorsal aspect of the body, have been discovered. Poli asserted that he saw a heart pulsating a little above the anus: but it does not appear that any other observer has made the same remark. Burmeister has searched, in vain, for a heart, in the large Coronula diadema. The vessels of the arms can be distinctly seen through the transparent integuments of the ciliated processes; there are, in each process, two vessels, one of which runs very superficially between the two rows of hairs. (*Fig.* 12.)

Cuvier regarded the anterior canal of the peduncle in Anatifa as the nourishing vessel of that organ.

Respiration.—The principal organs concerned in respiration are, in the Lepads, certain tapering filamentary processes attached to the sides of the anterior part of the body, which are regarded as the branchiæ (*d*, *g*, *fig.* 9): in most of the Balanids, they assume the form of two leaf-like membranes with fringed margins, and are attached to the inner surface of the mantle. Professor Burmeister describes the gills of Coronula diadema as broad membranous expansions, of a semicircular form, attached to the sides of the visceral mass by a narrow pedicle. They are composed of two tunics arranged in deep and narrow transverse plaits. The number of the branchiæ in the Lepads varies from four to sixteen. They are composed of soft cellular tissue, and have a smooth surface.

The arms (*h*, *h*, *fig.* 9), which constitute so large a portion of the general mass of all the Cirripeds, and which form their most distinctive feature, must be regarded as subservient chiefly to the function of respiration; although, by producing currents in the water, which bring food within reach of the jaws, they minister also to the digestive function. In all the known species, both of Lepads and Balanids, these arms are twelve in number, six on either side, arranged symmetrically. Each arm is composed of a short fleshy peduncle, having three articulations, and two horny articulated processes, compressed laterally, of equal length, ciliated on their internal surfaces, and coiled up in a spiral of one turn. On their internal surface there is a coating of a black pigment in spots. Each joint is provided with a double row of hairs of different lengths. (*Fig.* 12.)

Fig. 12.



A part of one of the arms considerably magnified.

In Anatifa, the first pair of arms is thicker and stronger than the others; the sixth pair is the longest. Dr. Grant says, "the arms are not only minutely jointed to their extreme points, but, also, the innumerable fine cilia which project inwards from their surface are themselves minutely jointed, and by the aid of the microscope, we can perceive that these jointed cilia are also ciliated on their margins."

When the animal is at rest, with the valves of the shell closed, the arms are coiled up, and lie close to one another; but, at other times, circumstances being favourable to the performance of the function of respiration, they are extended simultaneously so as to project from the shell,—radiate and plumose in their arrangement. Many species extend and contract their arms with considerable rapidity, as often as forty or sixty times in a minute; the smaller species more frequently than the larger.

Considering how extensive the surface is which is exposed in the arms between the two rows of cilia, and that a vessel seems to run immediately beneath the delicate covering of these organs in that situation, it appears probable that the arms are very efficient agents in the function of respiration.

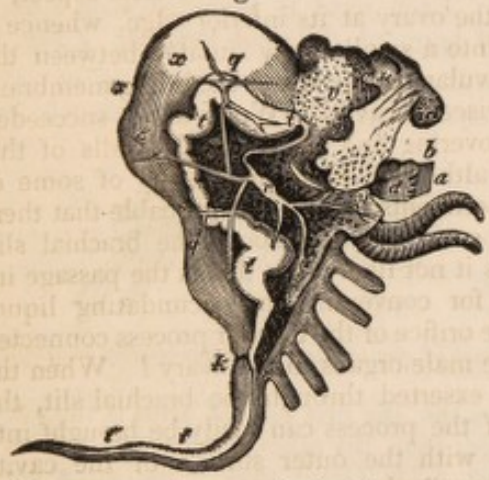
Secretion.—We have failed to ascertain satis-

factorily the structure of the secreting apparatus by which the shells of the Cirripeds are formed. In the Lepads, the organs must be imbedded in the ligamentous membrane by which the valves are united: and in the Balanids, they are arranged in six rows along the outer surface of the mantle, and around the base; but, as in acephalous mollusca, they are too small to admit of their structure being particularly examined. The external surface of the mantle in the Balanids has also the power of secreting calcareous matter, with which to increase the thickness of the shell.

Reproduction.—It is not yet accurately determined what are the organs of reproduction in these animals. That which was regarded by Cuvier as the ovary in the Lepads, is supposed by Professor Wagner and M. St. Ange to be the testicle; while Professor Burmeister has satisfied himself that it is the liver. The extent, structure, and relations of the ovary are still doubtful. It is certain, however, that all the known Cirripeds are hermaphrodite.

The testicle, according to Professor Wagner and M. St. Ange, is a large granular organ (*y*, *fig.* 13), expanded over the sides of the

Fig. 13.



visceral mass, and around the digestive canal, from the stomach to the anus, passing even into the bases of the arms, immediately beneath the muscular tunics which cover the body on both sides. It is composed of numerous minute lobules, about $\frac{1}{300}$th of an inch in diameter in the common Lepads, soft, white, grouped together by branched ducts (*q*, *q*, *fig.* 13), which, after uniting into three or four principal trunks,* meet in a large central receptacle (*r*), somewhat analogous in relative function to the *vas deferens* of vertebrate animals. The seminal fluid passes from this central receptacle by a short and straight duct into a large canal (*t*, *t*), which may be compared to the seminal vesicle. It pursues a tortuous course towards the base of the tubular process, where (*k*) it is joined by its fellow of the other side, and enters the canal of the process which forms a kind of caudal prolongation of the abdomen (*t'*, *t'*). This canal runs to the distal extremity, and opens by a minute orifice fringed with very fine hairs. In Otion Cuvieri the two canals are continued distinct to the very point of the process, where there are two openings.* The walls of the organ, which we have compared to the seminal vesicle, have a glandular structure, which Cuvier imagined to be the testicle. The researches of Professor Burmeister have led him to the same conclusion. He says it can be nothing but the testicle.† Cuvier, as well as Lamarck, regarded what we have called the testicle as the ovary, and believed that the ova were impregnated, in the course of their passage along the oviducts, by the seminal fluid flowing from the testicle investing these canals. The granular lobules of the true testicle, which were supposed to be immature ova, are found always in the same state, and what are more distinctly ova are found within the peduncle.‡

The lengthened tubular process (*t'*, *t'*, *fig.* 13), through which the excretory duct of the testicle passes, is articulated; the margin of each joint is fringed with minute hairs. In Otion and Coronula, Burmeister found large canals closed at both extremities, within the process, in addition to the ducts from the testicle. This organ is generally found after death bent upwards on the abdominal surface; but, during life, it is in continual motion. Its use is, probably, to carry the seminal fluid backwards beyond the current caused by the movements of the arms, in the event of there being mutual impregnation between separate individuals; or towards the mouths of certain ducts which communicate with the ovary within the peduncle, in case of self-impregnation taking place. In this view it must be regarded as the penis; and it is so called by the most recent authors on the subject—Wagner and Burmeister. Mr. Thompson calls it an *ovipositor*; and conjectures that, after their expulsion from the ovary, (understanding by this what we regard as the testicle,) the eggs are conveyed by it into the cellular texture of the pedicle. How they pass from this depository into the general cavity, where they afterwards form two or three foliated groups, he confesses himself unable to explain.

The peduncle of the Lepads was formerly regarded merely as an organ of support, and even Cuvier discovered within it nothing but what appeared to him to be a homogeneous pulp, surrounded by muscular tissue. But, at certain seasons of the year, at least, there are, very distinctly developed, throughout the greater part of the soft matter which constitutes the bulk of the organ contained within the dense cartilaginous and muscular tunics, certain oval granules, regular, and uniform in shape, and

* This description does not accord with the result of Professor Burmeister's researches. Instead of a regular series of branched vessels, he says that he met with nothing but an irregularly arranged mesh of thready fibres lying between what he believed to be the liver (described above as the testicle) and the intestinal canal.

* Burmeister, Beiträge, p. 46.

† Op. cit. p. 44.

‡ Professor Wagner is satisfied that nothing but the discovery of spermatic animalcules can assure us against error in our attempts to determine what is the testicle.

gradually increasing in size. Poli and Lamarck were of opinion that these were truly eggs, but held that they were originally formed in the granular organ surrounding the intestine, (now regarded as the testicle,) and merely deposited here temporarily. But the recent researches of Professor Wagner and M. St. Ange have rendered it probable that it is the ovary which is contained within the peduncle. The organ in question seems to occupy the whole of the peduncle within the layers of muscular tissue. It is separated from the visceral cavity by a fine membrane which lines that cavity, and is a reflexion of the mantle. A transverse section of the ovary shews the eggs most fully developed towards the outer margin, and scarcely formed in the centre. There are also seen in the same section two canals which run longitudinally through the organ, one near that side of the margin which corresponds to the anterior aspect of the body of the animal, the other in a similar situation on the dorsal aspect. Of these canals, the anterior is the larger; and it alone was described by Cuvier, who regarded it as connected with the circulating system. The other was first described by M. St. Ange, who satisfied himself that it is a true oviduct. In Anatifa, he traced it pursuing a straight course through the ovary, and leaving it as a perfect canal just at the posterior and inferior angle of the organ, thence passing on the outer surface of the lining of the visceral cavity, in the groove of the dorsal valve, and terminating in an orifice opening into the visceral cavity not far from the brachial slit.* We have found a structure exactly resembling the above in Otion, where, however, instead of opening into the general cavity of the visceral sac, the duct is bifurcated just between the two auriform appendages, into each of which one of the branches of the duct enters and opens. M. St. Ange found eggs in progress through this duct; and they are frequently found, arranged in groups or packets, two or three in number, within the cavity of the mantle. We have not yet seen them in the duct; but the whole structure of the parts in question seems to indicate their adaptation to the function assigned to them by M. St. Ange. This being the case with regard to Anatifa, it appears to be very probable that the use of the singular auriform appendages in Otion is to afford a convenient lodging for the eggs before the young are hatched. Their deep sinuosities and folds seem to adapt them admirably to this purpose. Packets of eggs, however, are found within the cavity of the mantle in this species as in others. According to Burmeister, these packets are unattached, excepting in the earliest stage of development; but Wagner has generally found them fixed to a process of the mantle, situated near the adductor muscle of the shell; which process is, at times, so much elongated as to admit of the eggs hanging out in groups from the brachial aperture, beyond the extremities of the arms. Burmeister has observed that, after the escape of the embryo, the shells remain connected with the parent, forming a loose net-work. This author seems to regard these groups of eggs within the mantle, and the tissue in which they are imbedded, as constituting the true ovary. In each of the individuals of Anatifa striata which came under his observation, he computed that there were about 4000 eggs in the ovary. Mr. Thompson calls these groups of ova *conceptacles;* and says that "each has a separate attachment at the sides of the animal to the septum, which divides the cavity occupied by the animal from that of the pedicle."* The retention of their ova, grouped in separate packets on the surface of their bodies, after their expulsion from the ovary, constitutes another point of resemblance between the Cirripeds and Crustaceous animals.

With regard to the anterior canal within the ovary, little has yet been determined. We have particularly examined it in Otion, and find that, like its fellow of the dorsal aspect, it leaves the ovary at its inferior edge, whence it opens into a small cavity situated between the intervalvular ligament and the lining membrane of the visceral cavity. We have not succeeded in discovering any orifice in the walls of this cavity, although, from the results of some of our experiments we think it probable that there exists a small one just above the brachial slit. If so, is it not likely that this is the passage intended for conveying the fecundating liquor from the orifice of the tubular process connected with the male organs to the ovary? When the body is exserted through the brachial slit, the point of the process can easily be brought into contact with the outer surface of the cavity above described.

The development of the egg and the young of the Cirripeds has recently become an object of interesting inquiry in consequence of the novel results announced by Mr. J. V. Thompson in his "Zoological Researches," (1830, 4th Memoir.) This gentleman has published an account of observations made on what he believed to be the young of Balanids, from which he concludes that, on their first exclusion from the egg, they closely resemble some of the branchiopodous crustacea,—that they possess the power of free locomotion through the water by means of setiferous arms projecting from within a bivalve shell,—and that they have very obvious pedunculated eyes. Minute animals, bearing these characters, and having some resemblance to species of the genus Cypris, were placed by Mr. Thompson in a glassful of sea-water. Soon after, on looking for them, he could not find them in the water, but he found in their room several very young balanids, which, from the appearance they presented, he concluded to be really the same animals that he had originally placed in the

* Professor Wagner says, "at the base of the dorsal valve there exists a slit in the mantle which leads into the canal that runs through the peduncle. I presume that this canal serves as an oviduct, and that the slit is analogous to the opening of the branchial canal in the bivalves," (in Archiv für Anat. Physiol. &c. von D. J. Müller, 1834, No. 5, quoted in Ann. des Sc. Nat. iv. n. s.) We are not aware what species was anatomized by Professor Wagner.

* Phil. Trans. 1835, 356.

water, changed by metamorphosis. Mr. Thompson has not seen the change actually going on, but he has satisfied himself that what he regards as the free-moving embryo fixes itself by a spot on its dorsal aspect between the two shells, which spot can be seen during its free state. When fixed, the base of adherence appears to be broad like that of an Actinia: from this it rises in a conical form, truncated. The flat sides of this cone are coated with six shelly plates, so arranged as to leave a large space in the middle uncovered. This space is closed by the old shells of the embryo state, which are made to move up and down as the opercule does in the adult animal, admitting of the egress and ingress of the arms at the animal's pleasure. Through this shell two large black spots like eyes can be distinguished. Mr. Thompson found in the young of the Balanids, six pairs of arms, cleft; each arm with two articulations. The first casting of the shell, after the animal has fixed itself, is followed by an increase in the number of articulations in each arm; and this number is further added to at every succeeding shell-casting. Even the old full-grown animals, according to Mr. Thompson, cast their shells.

Very recently Mr. Thompson has made a still more satisfactory series of observations on the development of some of the Lepads, of the genera Cineras, Otion, and Lepas. These he obtained from the bottoms of vessels in the harbour of Cork. They hatched eggs in large numbers, and afforded him the means of ascertaining, entirely to his own satisfaction, that, at its first exclusion from the egg, the Lepad, like the Balanid, is a *natatory crab*. He found a considerable difference between the *larvæ* of the two classes. The newly-discovered one of the Lepads he describes as "a tailed monoculus, with three pairs of members, the most anterior of which are simple, the others bifid, having its back covered by an ample shield, terminating anteriorly in two extended horns, and posteriorly in a simple elongated spinous process."

The general appearance of this larva is not unlike that of the *Argulus armiger* of Latreille.*

Very recently Messrs. Audouin,† Wagner,‡ and Burmeister,§ have corroborated the statements and supported the views of Mr. Thompson. Professor Burmeister has detailed the results of his observations with great minuteness. It appears that they were made chiefly on individuals of Anatifa striata, procured in the North Atlantic Ocean, and preserved in spirits; partly also on Lepas anserifera. (Linn.) The results of these observations have led Professor B. to divide the development of the Cirripeds into five stages or periods. The *first* of these is the state of egg; the *second* is that of free locomotion; the *third* is that in which the young becomes encased in a shell, and fixes itself; in the *fourth* stage, the young gradually assumes the characters of the adult; the *fifth* stage is that of perfect development.

First stage.—The egg. Its outer covering is a very delicate membrane. The yolk is yellowish-red, clouded, and marked with two rows of small spots, globule-like, distinct at one end, running together at the other. The eggs in the central parts of the ovary are considerably further advanced than those in the circumference. Through the transparent covering of the egg the general form of the embryo can be seen.

Second stage.—In this stage the young Cirriped resembles the fry of *Cyclops* or *Daphnia* in its external characters. It is provided with two long antennæ and three pairs of feet (arms?) placed along its ventral surface.* Each foot of the first pair is single, and is furnished with bristles at its free extremity. Each of the other pairs is divided into two members, also tipped with bristles. The posterior part of the body is tapering, compressed, and slightly bifurcated at its extremity, where it is beset with bristles. No eyes could be seen in this stage, but Professor Burmeister nevertheless conjectures that they really do exist. The appearance of two rows of small globules on the surface of the body continues to present itself, but here they are more numerous, although not larger. The middle part of the body is clear and transparent.

Third stage.—Materials for the description of this stage were obtained by Burmeister from the examination of only one individual, which was found attached to the frond of a fucus hard by the bases of some adult individuals. The shell, in this the first stage of its growth, is of leathery consistence, and formed of one piece, placed dorsally. A fleshy protuberance serves as the peduncle. The organs by which the young animal fixes itself are evidently the long antennæ situated near the mouth. Behind these are placed the very large eyes. Burmeister satisfied himself of the existence of a single transparent cornea, and saw behind it a round black spot, but no lens. The two eyes are very closely approximated by their bases. Both the eyes and the brownish contents of the alimentary canal can be distinguished through the translucent shell. In the structure of the posterior part of the body there is no great change from the former stage. Each arm of the first pair is single, and consists of three articulations, of which the basilar is the greatest: the smallest and terminal one bears four long stiff bristles. The arms of the following pair are not single, but each is divided into two small articulated processes. The little globules of the two former stages are not discernible in this.

* Phil. Trans. 1835, pt. ii. 355. "Discovery of the Metamorphosis in the second type of the Cirripeds," &c.

† Ann. des Sc. Nat. n. s. iii. 31.

‡ Müller's Archiv, No. 5, 1834, and Beiträge zur vergleich. phys. des Blutes. Leipzig, 1833.

§ Beiträge zur Naturgesch. der Rankenfüsser. Berlin, 1834.

* The circumstance of there being a smaller number of arms in the young than in the adult, reminds us of the same being the case in several of the Branchiopodous Crustacea; and the want of the shell in young Cirripeds seems to point out a closer analogy between them and Crustacea, than between them and Mollusca, the young of which are covered with shell in the egg.

Fourth stage.—This stage was observed by Professor Burmeister in the *Lepas anatifera* from the coasts of Chili. All the individuals examined were about three-fourths of a line in length. Soon after the animal fixes itself the old integuments are thrown off. The eyes and the antennæ are entirely cast off along with these. After this process had been completed, the space within the mantle was found to be filled with a granular pultaceous mass, at first occupying the greater part of the cavity of the shell, and covering all the young animal. This appeared to M. Burmeister to be the same that is found in the pedicle of the older animals, and to resemble closely the matter contained within the cavities of the shells of Coronulæ and other Balanids. It is by a sack-formed process of the mantle filled with this yellowish matter that the peduncle is first formed. At the time of the animal's fixing itself the shell has no calcareous points, but in the course of this stage it becomes firm and gradually more and more solid. There are now six pairs of feet, each of three articulations, and terminated by bristles. A small tail of two articulations also appears, the rudiments of which, however, can be detected in the former stage. In the *fifth stage* the process of development is completed.

It must be admitted that the evidence in favour of Mr. Thompson's opinions on this subject is by no means conclusive. There is still wanting a series of minute and careful observations on the first appearance and motions of the embryo immediately after its exclusion from the egg; and nothing but the results of such a series can settle the question as to whether there be a real metamorphosis or not.

Mr. Gray's observations have led him to conclude that no great changes of structure, such as Mr. Thompson's views presuppose, actually take place; although, in examining the mature egg of *Balanus Cranchii*, he found the appearance of the embryo nearly the same as is described by Burmeister as being that of the Lepads in the second stage of development. The egg of this Balanid Mr. Gray ascertained to be one-fiftieth of an inch in length. He describes the inclosed animal as being of an ovate form, tapering at one extremity, truncated and ciliated at the other; bearing a general resemblance to the adult animal, but furnished with only three pairs of ciliated arms; the base of each arm being two-jointed. He found only one lengthened process attached to the lower pair of arms; but, connected with the two upper pairs, two fusiform, thick, articulated and ciliated processes, similar to those of the anterior part of the perfect animal, but less elongated. He saw no shelly covering.*

We have not yet had proper opportunities of devoting attention to this interesting subject so far as observations on the living animals are concerned; but we have no doubt of its very soon meeting with a clear and satisfactory elucidation; meanwhile we may remark that the structure of the embryo within the mature egg (about which there can be no doubt) is such as strongly to indicate its adaptation to free locomotion; and that, after a review of all the observations that have been published on the subject, we are inclined to conclude in favour of Mr. Thompson's opinion that, in the early stages of its development, the young Cirriped really enjoys locomotive powers, and then undergoes such changes of structure as are required to fit it for its altered circumstances in adult age.

* Proceedings of Zool. Soc. Lond. 1833, pt. i. 115.

THE END.

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